CHANGES IN VISUAL SEARCH PATTERNS AS AN INDICATION OF ATTENTIONAL NARROWING AND DISTRACTION DURING A SIMULATED HIGH-SPEED DRIVING TASK UNDER INCREASING LEVELS OF ANXIETY

By

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The purpose of this investigation was to examine the influence of distraction on the attentional narrowing construct in the context of a dual task driving simulation under varying levels of anxiety. Forty-eight women were randomly assigned to one of six experimental conditions: *distraction control*, *distraction anxiety*, *relevant control*, *relevant anxiety*, *central control*, and *central anxiety*. Those assigned to *central* conditions only performed a driving task while the other four groups were required to identify peripheral lights in addition to driving. Those in *anxiety* conditions were exposed to increasing levels of anxiety which was manipulated by instructional sets. All

participants completed three sessions consisting of 20 trials each during which measures of cognitive anxiety , arousal, visual search patterns, and performance were taken.

Data indicated that as those in dual task conditions reached higher levels of anxiety, their ability to identify peripheral lights become slower and less accurate. Furthermore, the ability to drive for those in the *distraction* and *central* groups was impaired at high levels of anxiety. The decrease in driving proficiency for those in the *distraction anxiety* condition was highly associated with changes in visual search patterns which became more directed toward peripheral locations. In the *central anxiety* condition, driving proficiency was influenced by an increased tendency to make minor errors which could be attributed to a more cautious driving style when highly activated. Overall, performance on both central and peripheral tasks was worse for those in the *distraction anxiety* condition during the period of highest anxiety. Furthermore, visual search patterns were more eccentric during this session for this group.

Results suggest that drivers who are highly anxious and aroused experience an altered ability to process peripheral information at the perceptual level, leading to a decrease in attentional resources available for the processing of central information. In addition, it appears that this effect is amplified when distractors as well as relevant cues are present in peripheral areas. Implicated in the study is the role of visual search patterns and distractors in the dual task context. Suggestions are made to revise the current notion of attentional narrowing to include the role of distraction as a contributor to performance variability.

CHAPTER 1

INTRODUCTION

Anyone associated with sport as either an athlete, coach, or spectator, can remember instances in which the pressure of competition transcended the typical commentary that it was "just a game". Sport is replete with occasions such as a crucial free throw, a clutch base hit, a game winning field goal, or a breathtaking lap at the finish line, in which athletes either overcome the excessive demands of the moment and perform at their highest levels or choke under the extreme circumstances of the situation. More often than not, it is the ability to maintain concentration when faced with these stressors that determines the outcome of sport contests. However, even the greatest athletes occasionally succumb to these inordinate demands, causing sport psychologists to question why this occurs and what mechanisms contribute to diminished performance.

It has been suggested that the ability of athletes to execute effectively in exceptionally stressful environments is related to the impact of arousal and anxiety on the capability to maintain concentration. Though a number of researchers have suggested that excessive stress influences information processing capabilities by overloading the limited attentional resources available, much evidence provided to support this claim is anecdotal or observational in nature (Moran, 1996). Ignoring the underlying mechanisms

responsible for general changes in performance renders it impossible to prescribe competent interventions that specifically address the mechanisms which are being affected.

The paradigm shift in the study of cognitive psychology that occurred in the late 1950s and early 1960s brought with it a greater understanding of the specific processes that are involved with attending to and processing information. However, the research has been criticized due to its reductionistic nature. Ignored have been other relevant factors, particularly emotions that influence attentional processes and subsequent achievement (Kremer & Scully, 1994; Moran, 1996). By not studying the interaction of emotions, attention, and performance, the generalizability of research on attention has been somewhat limited. Thus, much still needs to be understood about dynamic sport settings in which attentional flexibility is crucial under conditions of severe time constraints and the stress associated with the competitive drive to win.

Of interest here is the peripheral (or attentional) narrowing phenomenon which has been reported to occur under high stress levels (Easterbrook, 1959). Though intriguing, and attracting much research interest to the present day, the underlying mechanisms responsible for the narrowing (or tunnel vision effect) which presumably occurs in stressful situations remain a mystery. Questions are still unanswered regarding the specific components of the stress response (i.e., cognitive or somatic anxiety, and/or arousal) that influence performance. Specifically, does narrowing occur due to heightened levels of cognitive anxiety, somatic anxiety, mere arousal, or some combination of these factors?

Another factor that has contributed to the confusion is that sport psychology researchers have been reluctant to give up the notion that the Inverted-U hypothesis

(Yerkes-Dodson, 1908) is the one and only description of the stress/performance relationship. However, contemporary models have been proposed that address the specific components of stress and prescribe testable hypotheses that are quite different from the very general Inverted-U description of the relationship of stress with performance.

Furthermore, the specific aspects of performance (i.e., stimulus detection and discrimination, response time, response accuracy, and others) that are influenced by changes in affective states have received relatively little empirical investigation due to the favoring of more easily understood global performance measures. As mentioned, by failing to address the specific parameters that are impacted by stressful stimuli, it is impossible to understand more precisely what is happening; and therefore, what to do about it.

Finally, many of the performance changes in stressful environments that have been attributed to attentional narrowing could possibly be explained in the context of distraction. In spite of their obvious application to understanding sport performance, the study of attentional narrowing and distraction in the context of dynamic sports is nonexistent.

As may be evident, advancement beyond current understandings of the stress/performance relationship is warranted for both theoretical and practical reasons. Thus, my intent was to investigate specific affective factors that influence attentional parameters and, ultimately, performance in an ecologically valid dual task situation under stressful circumstances. To provide further description of the specific issues to be

addressed and to justify the intended experiment, background information on the topics of interest follows.

Attentional Narrowing

It has been suggested that the ability to attend to, select, and process the most critical cues in a situation is one of the most important skills required for high level performance in sport (e.g., Abernethy, 1993). In support of this idea, experts have consistently exhibited what has been called a "cognitive advantage" over less skilled participants, being able to process the same information in a more efficient and effective manner (Starkes & Allard, 1993). Though this is interesting and valuable information for both cognitive and sport psychology researchers, the ability to demonstrate this cognitive advantage has rarely been investigated under imposed stressful states in a realistic sport context or other meaningful situation. However, an early theory that directly addressed the ability to select cues and use them effectively under different emotional conditions is the cue-utilization hypothesis described by the concept of attentional narrowing.

Easterbrook (1959) produced the most influential article on the topic of cue utilization based on the findings of Bahrick, Fitts, and Rankin (1952) and others (e.g., Bruner, Matter, & Papanek, 1955; Callaway & Dembo, 1958; Callaway & Thompson, 1953; Eysenck, Granger, & Brengelman, 1957; Granger, 1953). Easterbrook's primary theoretical contribution was the notion that as level of arousal increased to a certain point, performance in a dual-task situation would be variable between the two tasks. Specifically, he suggested that with an increase in activation to moderate levels, central task achievement would be facilitated due to the blocking of irrelevant cues in the

periphery from being processed. Furthermore, he postulated that at this moderate level, performance in tasks requiring less of a central focus (i.e., a peripheral focus) would deteriorate due to a blocking of these cues. Finally, performance in central tasks would be expected to deteriorate if arousal level reached a heightened state in which the funneling effect prohibited attention to relevant cues that are integral to performance of the central task. In other words, Easterbrook (1959) suggested that the degree of facilitation or disruption caused by emotional arousal is dependent on the range of cues needed to perform a task effectively and how those cues are attenuated by emotional states.

Unfortunately, relatively few investigations have been undertaken in sport settings to examine the effects of peripheral narrowing, or if this phenomenon exists. This is surprising considering that typical sport situations, especially at higher levels of expertise, often occur in extremely stress-provoking environments. In one of the only studies done in the context of sport, Landers, Wang, and Courtet (1985) investigated peripheral narrowing with experienced and inexperienced rifle shooters. The central task was a target shooting task and the peripheral task was an auditory detection task. Although there were no differences found in secondary task performance between the experienced and inexperienced shooters, both groups shot worse under high stress conditions.

Also with relevance to sport, two studies were conducted by Williams, Tonymon, and Andersen (1990, 1991) that substantiated Andersen and Williams' (1988) model of athletic injury. In the model, Andersen and Williams (1988) indicate that a possible predisposition to athletic injuries may be precipitated by elevated levels of life stress that result in an inability to attend to threatening peripheral stimuli. Support for this possibility

was provided by Williams et al. (1990, 1991) who showed that decrements in the ability to detect peripheral cues were found to occur while individuals performed Stroop tasks under stressful conditions. Based on their conclusions, the researchers suggested that attentional narrowing may be a dispositional factor that predicts athletic injuries because athletes are unable to notice potentially dangerous peripheral stimuli such as other players, dangerous terrain, and the like.

Though not directly sport-related, other perceptual-motor activities have been investigated with respect to the ability to attend to central and peripheral dual tasks. Of these, perhaps the most relevant to sport is driving an automobile (unfortunately, many highway drivers forget that it is not a sport!). While driving, there is a limited amount of attentional resources that can be devoted to an almost infinite number of stimuli at any point of time. As the task of driving becomes more complex due to decreased visibility, bad weather, heavy traffic, mechanical malfunction, sudden unexpected obstacles, fatigue, and other factors, the automaticity of driving becomes less instinctive and demands more attentional resources (Shinar, 1978). In these conditions, drivers may experience information overload and may be more likely to place themselves in possibly risky situations.

During normal driving, the driver tends to focus on the central task of keeping the vehicle "on the straight and narrow" so to speak, maintaining control of the vehicle based on the constraints of the driving environment (e.g., speed limits and lane markers). However, when confronted with an object or event that is not in the central (or foveal) field of vision, the eyes are normally moved from the central task to focus more directly on

the information that has been attended to in the periphery. Based on the information provided by the newly attended stimulus, a decision must be made regarding whether or not to change driving behavior. These alterations occur both in serial and in parallel depending on the specific situation presented (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). To make matters more complicated, all of these processes are often limited by extremely restrictive temporal constraints (Shinar, 1978).

Recent research has been directed toward understanding, more fully, the ability of drivers to extract meaningful information from signals along the roadway. In particular, many studies have been done on the demands of the external environment while driving, such as the perception and processing of road signs.

Hughes and Cole (1988) investigated the effect of attentional demands on eye movement behavior during simulated road driving. They attempted to assess how a driver's performance was effected by purposely directing attention to particular features of the road environment under single and dual task conditions. Results showed that across groups, 25% of the fixations were located at the actual focus of expansion while 80% of the remaining fixations were centered within 6 degrees of the focus of expansion. Therefore, results suggest that if road signs are located beyond the 6° point in the display, they will probably not be perceived. Also, increasing task specificity resulted in more fixations to the left part of the display (the area where most signs were posted) with a corresponding decrease in fixations to the center of the display. Furthermore, the addition of the dual task paradigm resulted in two predominant effects on eye movements. First,

eye fixations tended to move closer to the central region. Second, the distance of peripheral fixation also moved closer to the focus of expansion.

Therefore, it can be concluded that in the typical dual task condition which requires increased attentional resources, there is insufficient spare resources to perform the peripheral task without more fixation resources. The additional demand of the secondary task not only necessitates more fixations to the region of the task, but also reduces the extent to which the rest of the visual display is searched. Though not suggested by the researchers, these results could be accounted for in the context of attentional narrowing and/or distraction.

A similar study was conducted by Luoma (1988) to examine the types of roadway landmarks that are perceived and remembered better than others. As may be evident from the results of Hughes and Cole (1988), drivers do not perceive nearly all of the traffic signs that they encounter, even in situations where they have been precued to look for the signs. In situations imposing increasing demands and challenges to the driving task, the perception of signs is even less than in "normal" driving conditions.

Luoma (1988) tested the idea that the more casual the perception or the larger the target signs, peripheral vision is used to a greater extent. However, an important function of peripheral vision is to identify targets of importance to the driving task and, if the situations warrants, direct focal vision to the sign. To investigate these ideas, participants actually drove a 50 km route while outfitted in eye movement monitoring equipment. Results indicated that correct perception only occurred, for the most part, when the target was fixated foveally. Also, whether the sign was perceived or not depended heavily upon

the relevance of the sign to the driving task. For example, 100% of all speed limit targets were perceived foveally and were recalled while signs such as pedestrian crossings, roadside advertisements, and houses were perceived much less, if at all. In fact, no subjects recalled passing "pedestrian crossing" signs even though 25% of them fixated on it. It appears that the processing devoted toward identifying the signs was dependent upon the relevance of the sign to the actual driving task and its informativeness.

Perhaps the most relevant study reported to date to examine the processing of visual stimuli in both central and peripheral fields was conducted by Miura (1990). The primary purpose was to assess changes in the useful field of view (UFOV: the information gathering area of the display) under situations of varying task demands and to determine the corresponding variation in the acquisition of visual information that accompanied these changes. Mackworth (1976) has suggested that the UFOV will vary with changes in the situational characteristics or specific demands of the environment. The study was conducted under actual driving conditions in which the subject had to navigate along a roadway, in daylight conditions.

Results showed that RT to peripheral lights increased as the situational demands increased. Furthermore, response eccentricity became shorter, suggesting that fixations had to occur closer to the actual target location to acquire the necessary information. In general, this suggests that peripheral visual performance is impeded by an increase in situational demands. Specifically, it appears that the UFOV narrowed at each fixation point, and the latency of each fixation lengthened. Also, the detection of targets required a greater number of eye movements in more demanding driving situations.

To explain these findings, Miura (1990) postulated that the depth of processing of an object in focus increases as the situational demands increase. Specifically, the latency period of the eye movements following fixation on a target lengthens as the demands increase. In more demanding situations, when a narrower UFOV exists, information pickup at the fixation point appears to be slower, causing a delay in the attentional switching capabilities of the driver. Other evidence (Miura, 1985) indicates that with lower demands, the fixation points shift to the inner area of the UFOV while during highly demanding situations, fixations shift toward the outer part of the UFOV. Thus, as a result of the deeper processing that occurs at each fixation point, participants attempt to acquire information more efficiently in the periphery while using a smaller UFOV. Another hypothesis is that as demands increase, they develop a stronger tendency to search for information in the periphery, a phenomenon referred to as "cognitive momentum", and a possible adaptation of the system to utilize attentional resources in the most efficient manner to deal with the increase in demands (Miura, 1986).

Though interesting and conceptually valuable, Miura's (1985, 1986, 1987, 1990) work fails to take into account what might be a primary influence on the decrement in peripheral performance and the apparent narrowing of the UFOV. Though not mentioned in any of his papers, a possible explanation for these findings can be attributed to the increase in arousal and anxiety that accompanies tasks that increase in complexity and demands (Easterbrook, 1959). Although eye movements have been recorded in a variety of real world and simulated driving situations, researchers have not attempted to examine other affective inputs to the system that may account for differences in performance.

Furthermore, in Miura's (1990) study, as well as others, performance in the central driving task was not recorded.

Like normal driving, the sport of auto racing demands the coordination of an extensive repertoire of perceptual and motor skills. However, the performance difficulty of these skills is significantly compounded by the competitive nature of the sport. In addition to mastering typical driving skills, the shear speed of the car requires split-second decision-making and intense concentration on the most relevant cues for the entire duration of the race. An ill-advised momentary attentional shift or distraction can be (and often is) catastrophic under these circumstances. Unfortunately, virtually no attempt has been made to empirically assess these factors in auto racing.

As may be evident from the sparse research that has been conducted related to sport and driving, no study has addressed the issue of attentional narrowing in the context of dynamic, reactive sport environments. However, perhaps the theoretical mechanisms that underlie results from laboratory tasks and the few sport situations that have been studied are common to all dynamic sports as well.

The reduction in the range of cue utilization was originally explained in the context of both Hull's (1943) Drive theory and the Yerkes-Dodson (1908) Inverted-U hypothesis. However, the cue utilization hypothesis can be more accurately accommodated with more recent attentional capacity (or resource) theories (Kahneman, 1973: Wickens, 1984) which propose a limit in the resources available to attain optimal attention. Proponents of this view (e.g., Landers, 1980) suggest that one primary feature of high arousal levels is a narrowing of attention because the allocation policy is likely to shift away from the

periphery and toward the central area of a visual display. This notion has been supported by studies that indicate the probability of cues in central areas of a display to draw more attentional resources increases under stressful situations (e.g., Hockey, 1970).

To summarize the attentional narrowing point of view, stress (either arousal or anxiety produced) tends to overload the system, narrowing the range of stimuli that are perceived. When this occurs, information processing capabilities appear to operate in a dysfunctional manner. At the initial stages of perception, possibly various cues are ignored, never reaching later stages of processing. On the other hand, the actual informational value of the stimulus may not be utilized effectively due to an inability to distinguish the stimulus as relevant or irrelevant and respond accordingly. Thus, narrowing could be due to a dysfunction at the perceptual stage of processing and/or at the short term memory stage. Quite possibly, impairment occurs at both stages of information processing (Bacon, 1974; Hockey, 1970). However, the exact location of information processing dysfunction has not been substantiated. Furthermore, an alternative explanation for what happens to performance and attentional allocation under stressful conditions is plausible.

Distraction

As described previously, the idea that consistently recurs as an explanation for performance changes in both central and peripheral tasks in stressful environments is a narrowing of the attentional beam in which cues are somehow filtered from processing at either the perceptual or encoding stage of analysis. However, the influence of distractors in the context of peripheral narrowing has not been investigated, and the concept of

distraction has received very little attention from researchers. It seems logical, however, that the apparent narrowing of attention that occurs under stressful conditions could also be explained by the notion that anxious or aroused performers are more inclined to be distracted.

The lack of research directed toward understanding distraction is surprising considering the need of people in many work, entertainment, sport, and other situations to ignore distractors and focus only on the most critical cues in order to effectively perform the task. Examples of athletes and other performers who have been victimized by distraction are numerous (Moran, 1996), prompting Orlick (1990) to suggest that the need to avoid distraction is one of the most important mental skills required to be successful in sport.

Brown (1993) defines distraction as situations, events, and circumstances which divert one's mind from some intended train of thought or from some desired course of action. This definition is somewhat different from William James' (1890) original conceptualization of distraction which was directed toward the experience of distracting thoughts and being "scatter-brained". Each of these views of distraction can be more easily understood if categorized in the context of internal and external types of distractors (Moran, 1996). Internal distractors refer to mental processes that interfere with one's ability to maintain attention while external distractors are environmental or situational factors that divert attention from the task at hand. Wegner (1994) has postulated that because the mind tends to wander, an attempt is made to hold it in place by repeatedly checking to determine whether it has wandered or not. However, in this process, the mind

is inadvertently drawn to the exact thing that one is trying to ignore. He also suggests that when highly emotional, attentional resources are reduced, and the mind is inclined not only to wander away from where it should be attending, but is also diverted toward that which one is attempting to ignore.

The typical effect of distraction is a decrease in performance effectiveness. The most plausible explanation for this is that when one is distracted by either external or internal factors, there is a decrease in available attentional resources for the processing of relevant cues. Like attentional narrowing, this idea is consistent with the limited capacity models of attentional resources proposed in different forms by various attention theorists (e.g., Allport, 1989; Kahneman, 1973; Shiffrin & Schneider, 1977). Because attentional capacity is limited, resources directed toward the processing of distractors reduce available resources for the processing of task-relevant information. This idea is supported by studies which have shown that distraction effects increase for complex rather than simple tasks and are greater as the similarity of distractors to relevant cues increases (Graydon & Eysenck, 1989).

Though empirical evidence is scarce, many researchers have suggested that increases in emotionality (i.e., anxiety, worry, arousal) increase susceptibility to distraction. Numerous examples of evidence to support the notion that stress impedes performance due to distraction can be found in verbal accounts and behavioral observations of "choking" in competitive environments. Moran (1994, 1996) provides substantial anecdotal evidence that the impact of anxiety is the absorption of attentional resources which could otherwise be directed toward the relevant task. Similarly,

Baumeister and Showers (1986) suggest that increased worry causes attentional resources to be devoted to task-irrelevant cues. Furthermore, self-awareness theorists such as Masters (1992) suggest that under stress, not only is attention absorbed by irrelevant stimuli, but also the performance of normally automated skills becomes less automated as resources begin to be intentionally directed toward the process of the once-automated movement. Finally, Eysenck (1992) has provided empirical evidence that anxiety provokes people to detect stimuli which they fear, usually stimuli that diverts them from attending to relevant information. Unfortunately, the specific components of stress that influence attentional parameters have also been largely ignored.

Arousal and Anxiety

Due to increasing dissatisfaction with the Inverted-U hypothesis and other theories, researchers attempted to analyze the stress response in greater detail as to its various components and to re-examine the stress/performance relationship. Perhaps the first scholars to approach the possibility of dissecting the general anxiety response were Liebert and Morris (1967) who identified two primary contributing factors to anxiety: worry and emotionality. In Liebert and Morris's view, worry consisted of cognitive concerns about one's performance while emotionality referred to the autonomic reactions to the performance environment. This concept strongly influenced Davidson and Schwartz's (1976) multidimensional model of anxiety. They were the first to use the terms "cognitive" and "somatic" anxiety and formulated their theory in the context of clinical applications. Thus, worry has become synonymous with cognitive anxiety and emotionality has become synonymous with somatic anxiety. These general characteristics

of the components of anxiety have held up under empirical investigation and appear to be manipulable independently (e.g., Schwartz, Davidson, & Goleman, 1978). Also, it is important to distinguish both components of anxiety from arousal. Though similar to somatic anxiety, arousal refers to the natural physiological indices of activation that are present within an organism at any time (Sage, 1984). In contrast, somatic anxiety refers to the perception of physiological arousal.

One problem with multidimensional anxiety theory is the two-dimensional approach used to explain the effects of somatic and cognitive anxiety on performance. Specifically, the two-dimensional approach in analyzing results tends to neglect the *interaction* of the components of stress, treating them independently rather than in combination (Hardy & Fazey, 1987). According to the viewpoint of Hardy and his colleagues, any relatively comprehensive treatment of these components must treat them in an interacting, three dimensional manner. To improve the predictability and structure of the model, therefore, Hardy and Fazey (1987) developed a catastrophe model of anxiety and performance.

In an effort to advance understanding beyond the multidimensional approach to the study of the effects of anxiety and arousal on performance, Fazey and Hardy (1988) proposed a three-dimensional model of the relationship. Borrowing heavily from Thom (1975) and Zeeman (1976) who originally conceptualized the idea of catastrophes and then applied them to the behavioral sciences, respectively, Fazey and Hardy's (1988) model is closest in form to the cusp catastrophe, one of the seven originally proposed

catastrophe models of Thom (1975). According to the cusp catastrophe model, changes in either cognitive anxiety or arousal, or both will change performance in specific ways.

Hardy and Fazey (1987) state that of the two variables that determine behavior (cognitive anxiety and arousal), cognitive anxiety is the "splitting factor", the variable that has the primary influence on performance level. The roles of cognitive anxiety and physiological arousal were chosen specifically to be able to evaluate testable hypotheses with respect to the anxiety/arousal/performance relationship. Specifically, when cognitive anxiety is low, the model predicts that physiological arousal will influence performance in an inverted-U fashion. However, when physiological arousal is high, high levels of cognitive anxiety will result in lower levels of performance. Finally, when physiological arousal is low, higher cognitive anxiety will lead to increases in performance.

Usually the manipulation of anxiety and arousal is carried out through a time-to-event paradigm in which assessments are taken at specified times leading up to a competition setting (Hardy, Parfitt, & Pates, 1994). For instance, assessments will be taken one week prior, two days prior, and then one hour prior to the competition. In this way, the time course of anxiety and arousal can be assessed. In other instances, levels of anxiety and arousal are manipulated through the use of both ego-threatening or other anxiety-producing instructional sets and through the use of exercise-induced arousal, respectively (Parfitt, Hardy, & Pates, 1995).

An obvious feature of the cusp catastrophe model of the anxiety/performance relationship is the choice of physiological arousal rather than somatic anxiety as the normal factor. The primary reason for this choice is based on the notion that it is part of the

organism's natural physiological response to anxiety-producing situations (Hardy, 1996). This belief is sufficiently well-established to be spoken of in the context of a generalized response within the competition setting. In other words, in competitive environments, performers usually show one or more signs of physiological arousal. Though the physiological response may be reflected in self-reports of somatic anxiety, the purely physiological index can encompass the individual task requirements, different situations, and other combinations of factors that override reports of somatic anxiety. Furthermore, physiological arousal changes tend to be reflected in changes of somatic anxiety while the converse is not the case (Fazey & Hardy, 1988; Hardy, 1996; Hardy & Fazey, 1987). Substantial support has been shown for the cusp catastrophe model of the anxiety performance relationship in seminal investigations of the model by Hardy and his colleagues (e.g., Hardy, Parfitt, & Pates, 1994).

One limitation, however, to the study of stress and performance in the context of any of the models described previously, is a lack of empirical explanation for the performance changes that are noticed in overly stressful situations. As mentioned, one specific cognitive mechanism that has been implicated, but has received limited empirical investigation in sport contexts, is the impact of anxiety and arousal on attentional resources. Thus, a logical next step is to attempt to delineate these relationships in an effort to more thoroughly understand performance changes under stressful conditions.

A More Comprehensive Next Step

Though intriguing and receiving much anecdotal support in a variety of settings, the empirical interaction between the cognitive and emotional antecedents of the

stress/performance relationship remains largely unspecified. Furthermore, in light of recent dissatisfaction with the Inverted-U hypothesis of the anxiety/arousal/performance relationship, the underlying explanations originally forwarded by Easterbrook (1959) may be somewhat obsolete. Specifically, although studies in which anxiety or arousal have been manipulated have shown support for the attentional narrowing phenomenon, none have examined the interactive effects of these emotional antecedents, nor have they designated one or the other as the primary contributor to the relationship. Furthermore, the role of distraction has received little or no investigation in this context, and an understanding of it could contribute greatly to the understanding of performance changes.

Paradoxically, it appears that perhaps there are two equally attractive explanations for the decrease in performance that occurs under high levels of stress. On one hand, proponents of the attentional narrowing argument would suggest that under high stress levels (either anxiety or arousal induced) the attentional field narrows to block out irrelevant cues, and then narrows further, blocking the processing of relevant information as stress continues to increase. On the other hand, proponents of the distraction argument would suggest that actually a widening of the attentional field occurs such that irrelevant or distracting cues receive more attention than when under lower stress levels. Evidently, a controversy exists unless in some way, both mechanisms could be working at the same time. Perhaps, an increase in anxiety and/or arousal results in a narrowing of the attentional field while at the same time, especially at higher levels of stress, it increases susceptibility to distraction. Many theories can account for how stress affects attention

and the eventual impact of attentional variation on performance, but none address specifically why this phenomenon occurs.

As may be evident from the discussion of driving tasks, visual search has been used extensively to draw cognitive inferences regarding what information is being extracted and processed during eye fixations, a concept Viviani (1990) has termed the "central dogma" of visual search research. Though it is presently impossible to empirically prove the central dogma, most researchers agree that eye fixations do at least reflect cognitive processing. Assuming the dogma to be even partially true, if an attenuation of cues in the periphery is evident, the need to pick up crucial cues in the periphery during particular situations would necessitate an increase in scan path variability and fixation rate in order to compensate for peripheral narrowing. Furthermore, if distracting visual cues were actually introduced into the test environment, visual search strategies may be altered, resulting in increased fixation and processing of distracting stimuli and a reduction of attentional resources available for central task performance.

Like normal driving, the sport of auto racing demands the coordination of an extensive repertoire of perceptual and motor skills. However, the performance difficulty of these skills is significantly compounded by the competitive nature of the sport. In addition to mastering typical driving skills, the sheer speed of the car requires split-second decision-making and intense concentration on the most relevant cues. An ill-advised momentary attentional shift or distraction can be (and often is) catastrophic under these circumstances. Thus the need to respond effectively in this type of a pressure-packed

activity is paramount. Unfortunately, no attempt has been made to empirically assess these factors in auto racing.

Viviani (1990) suggested that the central dogma of visual search and cognitive inference would be valid if evidence for serial search is provided in particular tasks. According to Kahneman (1973), as arousal increases, task difficulty also increases. Under these circumstances, parallel (relatively automatic) processes tend to be modified by the organism, becoming more serial and attentive in nature (Duncan & Humphreys, 1989; Shiffrin & Schneider, 1977). As mentioned, the auto-racing environment is one is one in which drivers experience extremely high levels of arousal and anxiety. In this case, the ability to relate eye fixations to cognitive information processing is more valid than when parallel processing is dominant.

As mentioned, very limited research has been done to investigate any psychological phenomena with auto racing and none has been done to investigating driver's eye movements or other attentional parameters that are critical to high performance in the fastest sport in the world. The selective and divided attention demands of race car driving render it an ideal task and environment to investigate attentional mechanisms and the eye-movement parameters that underlie those mechanisms. Perhaps the first step that should be taken to better understand the attentional capabilities necessary for effective race car operation is to evaluate the visual search patterns of drivers as they navigate the race course. By evaluating these parameters, it may be possible to assess whether the "software" advantages that appear to predispose athletes in other sports to reach higher levels of achievement are valid antecedents to high performance auto racing.

In light of these considerations, the primary objective of this study was to attempt to delineate the individual and interactive influence of arousal and cognitive anxiety on attentional capabilities. In addition, it was anticipated that these attentional alterations would result in behavioral changes that would, in turn, influence global performance indicators. Specifically, performance while undertaking (1) a central driving task and (2) a peripheral light identification task was investigated under various levels of cognitive anxiety. Furthermore, visual search patterns were assessed to ascertain whether perceptual factors (i.e., the search patterns themselves) contributed to the attentional narrowing and/or distractibility phenomena.

In this manner, an attempt was made to isolate specific factors that might influence selective attention and the ability to divide attention between the central and peripheral tasks. Also, an attempt was made to determine whether visual search patterns were influenced by changes in both cognitive and physiological activation levels. By assessing specific dependent measures rather than simply global changes in affect, cognition, and performance, a clearer understanding of the interactive influence of these factors was acquired.

Statement of the Problem

In this experiment, a central driving task and a peripheral light detection task were used to assess the effects of anxiety (as manipulated by a time-to-event paradigm and anxiety-producing instructional sets) on performance over the course of familiarization, practice, and competition sessions. Performance-related variables included: (a) driving speed and accident propensity, (b) peripheral light detection speed and accuracy, (c) visual

search patterns, and (d) physiological arousal. Determined was whether any anxiety-induced changes in performance were due to a narrowing of the attentional field, increased distractibility, or both.

Hypotheses and Pilot Study Results

The following hypotheses were tested in this investigation. The first set of hypotheses was directed toward the manipulation of anxiety and the expected result of this manipulation on arousal levels. Rationale for the hypotheses is offered after all are proposed.

1. The use of the time-to-event paradigm and instructional sets will produce higher cognitive anxiety levels during the practice and competition sessions in the experimental groups (anxiety) than in the control groups (no anxiety) as measured by the CSAI-2 (Martens et al., 1990). The instructional sets used will be similar to those employed by Hardy et al. (1994) and will be used to manipulate levels of cognitive anxiety independent of somatic anxiety. These manipulations have been shown to be valid in both sport-specific (Hardy et al., 1994) and other evaluative situations (e.g., Morris, Harris, & Rovins, 1981). Furthermore, the time-to-event paradigm has been a reliable means of investigating temporal changes in anxiety associated with impending competitions (Hardy et al., 1994).

2. The increase in anxiety levels exhibited in the experimental groups will be mirrored by an increase in physiological arousal (as measured by an increase in heart rate and pupil diameter size) in the practice and competition sessions. In addition, it is

hypothesized that cognitive anxiety and arousal levels will be highest immediately prior to the competition session due to the time-to-event and instructional set manipulations.

According to Lacey and Lacey's (1958) autonomic response stereotype hypothesis, the reaction to anxiety-producing thoughts and stimuli cannot be specified due to individual differences. However, if manifested in physiological changes, heart rate and pupil dilation measures are sensitive to increases in autonomic activity. In addition, heart rate has been used reliably in other tests of the catastrophe model of anxiety (e.g., Hardy et al., 1994). Furthermore, Abernethy (1993) has advocated the use of pupillometry as one of the most reliable measures of anxiety. Finally, because the test environment is static, such that the participant is not physically activated in any way, any changes in HR or pupil dilation across test conditions can be more readily attributable to emotional changes than if tested in a physically active situation.

The next set of hypotheses was directed toward the anticipated changes in performance that were expected to occur in the central and peripheral tasks.

1. For *central* task conditions (those in which only the central driving task is performed), driving performance (as measured by lap speed and the number of driving errors) will be similar for the *control* group and *anxiety* group in the familiarization session. However, during the second session, driving is hypothesized to be more proficient for the *anxiety* group than the *control* group. Finally, performance in the competition session will be better for those in the *control* group than those in the *anxiety* group.

2. Those in the *relevant* groups, in which the central driving task will be performed concurrently with peripheral light identification of relevant stimuli, will exhibit similar proficiency on both tasks regardless of control or anxiety manipulations during the familiarization session. Driving skill during Session 2 (practice) is predicted to be facilitated for those in the *anxiety* group as opposed to the *control* group, but performance in the peripheral light detection task (as measured by reaction time and response accuracy) will be diminished due to a decrease in peripheral cue utilization. In the third test session (competition), those in the *anxiety* group will perform worse in both tasks due to a decrease in cue utilization.

3. For the dual task *distraction* conditions (those in which the central driving task will be completed concurrently with peripheral light detection of relevant stimuli while ignoring irrelevant peripheral lights), achievement in both tasks during the familiarization session will be similar for the *anxiety* and *control* groups. Central driving task proficiency during the second session will be facilitated for those in *anxiety* groups as opposed to *control* groups, but peripheral cue utilization changes will result in reduced performance on the peripheral light detection task during the same session for the *anxiety* group. In the third session, execution of both tasks will be worse for those in the *anxiety* condition as compared to *control* groups due to an increase in the narrowing of cue utilization as well as an increase in the distractibility of participants at high levels of anxiety.

4. Overall, achievement in the central driving task should be highest for the *central control* group in the third test session due to no interference from anxiety or other attention-demanding stimuli (i.e. peripheral lights). The ability to detect peripheral lights

should be best for the *relevant control* group in the competition session due to the increased automation of the central task, no interference from distractors, and no interference from anxiety changes. Furthermore, reaction time and detection accuracy for relevant peripheral lights in the *distraction* condition is expected to be similar in the familiarization session for *anxiety* and *control* groups. However, detection speed and accuracy will decrease for those in the *anxiety* group in the competition session due to an increase in distractibility.

These hypotheses were forwarded on the basis of previous conclusions from studies of the attentional narrowing phenomenon (e.g., Bruner, Matter, & Papanek, 1955; Callaway & Dembo, 1958; Callaway & Thompson, 1953; Eysenck, Granger, & Brengelman, 1957; Granger, 1953), as well as a variety of anxiety models that indicate a moderate increase in activation to be beneficial to performance but a high level of activation to result in diminished achievement (e.g., Hardy & Fazey, 1987; Yerkes-Dodson, 1908).

According to the attentional narrowing phenomenon, under moderate levels of anxiety and arousal, the range of cues utilized will be decreased, blocking peripheral cues from being processed. Thus, central driving task proficiency will be facilitated by maintaining attentional focus on the most relevant cues while performance on the peripheral light detection task will be hindered (Easterbrook, 1959; Kahneman, 1973). However, as activation levels increase, a person is most likely susceptible to a further decrease in the range of cue utilization, blocking the processing of relevant cues (Easterbrook, 1959). Also, remaining attentional resources may be absorbed by the

increased propensity to be distracted by both internal factors (anxiety) and an increased propensity to process irrelevant external factors (distracting peripheral stimuli) (Moran, 1996; Wegner, 1994).

If activation levels reach extremes, this could eventually result in a catastrophic deterioration in effective execution (Hardy, 1996) of both central and peripheral tasks. Specifically, Hardy and Fazey's (1987) catastrophe model indicates that when a performer's cognitively anxiety and arousal reach high levels, performance will deteriorate in a dramatic fashion, not in a gradual manner as proposed by the Inverted-U hypothesis (Yerkes-Dodson, 1908).

The final set of hypotheses was directed toward the expected changes in visual search patterns that were expected to be exhibited by participants in response to changes in anxiety and arousal levels. Once again, at the completion of the proposed hypotheses, rationale will be presented.

1. Eye fixations for those in the *central* condition are expected to cluster closely around the point of expansion (within a 6° radius from the point of expansion) for both the control and anxiety groups.

2. In the *relevant* condition, fixations for the control groups should be focused more centrally (similar to the *central* condition) than for the *anxiety* group due to the ability of *control* participants to acquire peripheral stimuli information with peripheral vision. Correspondingly, those in the *anxiety* group will probably exhibit an increase in the number of fixations to the periphery in order to compensate for the reduction of peripheral vision due to anxiety.

3. In the *distraction* condition, similar to the *relevant* condition, fixations for the *control* groups are expected to remain more centrally located in Sessions 2 and 3 due to the ability to discriminate relevant from irrelevant peripheral light stimuli with peripheral vision. However, the number of fixations to the periphery for those in the *anxiety* group will increase in Session 2 and then even more in Session 3 due to a narrowing of cue utilization and an inability to acquire peripheral information with peripheral vision, as well as the increased susceptibility to focus on distracting stimuli.

These hypotheses are based on findings from general studies of driver fixation tendencies as well as the previously mentioned hypotheses with respect to attentional narrowing and distraction. It has been repeatedly shown that 80-90% of drivers' fixations tend to cluster within 4-6° of the point of expansion in the visual display and that this tendency is enhanced under conditions of higher task complexity (Miura, 1985, 1990). These tendencies would be expected to hold for those in *control* groups that do not experience extremely high levels of anxiety and are not required to process peripheral input. However, under anxiety-producing conditions, the visual field is expected to narrow (Easterbrook, 1959), requiring an increased number of fixations to the periphery to acquire information that is normally acquired by peripheral vision.

Furthermore, it would appear that highly anxious and aroused participants will increase the number of fixations to distracting stimuli. Miura (1986) has suggested that as driving demands increase, a stronger tendency to search for information in the periphery occurs. Accordingly, this is a possible adaptation of attentional processing to deal with the increase in demands (Miura, 1987). In terms of distraction, resources (i.e., eye

fixations) directed toward the processing of distractors reduce available resources for the processing of task-relevant information. Graydon and Eysenck (1989) have shown that distraction effects increase for complex rather than simple tasks and are greater as the similarity of distractors to relevant cues increases. As the ability to distinguish relevant from irrelevant cues is diminished, the propensity to be distracted by irrelevant stimuli will likely increase along with the tendency to fixate on these stimuli.

Definitions of Terms

To standardize the terminology in this experiment, the following terms are defined:

Arousal is the process in the central nervous system that increases the activity in the brain from a lower level to a higher level, and maintains that higher level. The activation response is a general energy mobilizing response that provides the conditions for high performance, both physically and psychologically (Ursin, 1978).

Attention is "...the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization , concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others" (James, 1890, pp. 403-404). Also, it has been described as a concentration of mental activity (Matlin, 1994; Moran, 1996).

Attentional narrowing refers to the phenomenon in which, under increasing levels of stress, the range of cues utilized by an organism is reduced, resulting in an initial filtering of irrelevant or peripheral cues from processing, an increase in performance of central tasks, and a decrease in performance of peripheral tasks. As stress levels continue

to increase, both task- irrelevant as well as relevant cues begin to be attenuated from processing until performance in both peripheral as well as central tasks are disrupted (Easterbrook, 1959).

Cognitive anxiety is characterized by worry or the awareness of unpleasant feelings, concerns about performance, and the inability to concentrate (Rotella & Lerner, 1993).

Cusp catastrophe model is a three-dimensional model that describes how one dependent variable can demonstrate both continuous and discontinuous changes in two other dependent variables. In the context of the catastrophe model of anxiety, the dependent variable is performance and the two independent variables are anxiety and arousal (Hardy, 1996).

Distraction refers to situations, events, thoughts, or circumstances that divert the mind from some intended train of thought and tend to disrupt performance (Brown, 1993; James, 1890; Moran, 1996).

Divided attention is characterized by the ability to attend to several simultaneously active messages or tasks, or to distribute attention effectively to simultaneous tasks that develops as a result of experience and practice (Eysenck & Keane, 1995; Hawkins & Presson, 1986).

Fixation refers to a pause in search during which the eye remains stationary for a period equal to or in excess of three video frames (120 ms) (Williams, Davids, Burwitz, & Williams, 1994).

Fixation location refers to the areas in the display in which the eye fixates during completion of a task (Williams, Davids, Burwitz, & Williams, 1994).

Point of expansion (POE) is the area where the two edge lines of the road appear to converge and the point at which the road appears to expand outward from the center (Rockwell, 1972).

Reaction time (RT) refers to the elapsed time between presentation of a particular stimulus and the initiation of a response to that stimulus (Schmidt, 1988).

Saccadic eye movements refer to movements of the eyes from one fixation point to another. A common saccade lasts for approximately $1/50^{th}$ to $1/10^{th}$ of a second depending on how far it is to the next fixation (Andreassi, 1989).

Search Rate refers to a combination score representing the number of fixations and the duration of each fixation at particular locations (Williams, Davids, Burwitz, & Williams, 1994).

Selective attention refers to "the process of selecting part of simultaneous sources of information by enhancing aspects of some stimuli and suppressing information from others" (Theeuwes, 1994, p. 94).

Somatic anxiety refers to perceptions of physiological arousal such as shakiness, sweating, increased heart rate, rapid respiration, and "butterflies in the stomach" (Martens et al., 1990).

Stress is characterized by a combination of stimuli or a situation that is perceived as threatening and which causes anxiety and/or arousal (Hackfort & Schwenkmezger, 1993).

Useful field of view (UFOV) refers to the information gathering area of the visual display (Mackworth, 1976).

Visual search refers to the two-stage process in which visual information from sensory receptors is held in a rapidly decaying visual sensory store and then selected items in the iconic store are subjected to a more detailed analysis (Jonides, 1981; Theeuwes, 1994).

Assumptions

For the purposes of this investigation, the following assumptions were made:

1. Participants received course credit for participation and therefore should have been equally motivated to participate in the study.
2. The time-to-event paradigm and specific instructional sets which include possible ego threats, monetary gain, and other incentives, were appropriate methods to manipulate cognitive anxiety (Hardy, Parfitt, & Pates, 1994).
3. The CSAI-2 (Martens et al., 1990) was an appropriate measure of cognitive anxiety.
4. Heart rate and pupil diameter measures were accurate and appropriate indices of arousal (Abernethy, 1993; Hardy, 1996).
5. The dependent measures used to assess central driving task performance (lap speed and number of errors) and the peripheral tasks (RT and number of errors) were appropriate measures of performance.
6. The central dogma that the line of sight will coincide with the direction of attention (Viviani, 1990) was at least partially true in this case, and therefore, visual search orientation was reflective of the participant's actual allocation of attention.

Significance of the Study

Most empirical research dealing with the interactive effects of arousal and/or anxiety with performance has been oriented in a in a very general fashion. This is exemplified by the global measures of both stress and performance that have been used (Jones, 1990). Therefore, very little is known regarding the specific components of the stress response (either cognitive anxiety, arousal, or both) that influence performance variables such as attentional flexibility, speed of information processing, decision-making, and other cognitive factors. With this in mind, the primary intention of the study was to contribute to and expand upon the established bodies of knowledge regarding the ability of participants in competitive sports and other stress-inducing activities to attend to and process the most relevant cues and make decisions appropriately. Though a driving task was used in the study, the implications of this research are intended to be generalizable, to a certain extent, to other achievement situations in which the stress response occurs. The driving simulation provided an ecologically valid, natural dual task paradigm in which to ideally investigate the phenomena of interest due to the need to attend to and process cues from both central and peripheral locations while driving.

The investigation addressed five issues of theoretical importance. First, a greater understanding was provided of the decrement in performance that has been repeatedly shown while completing tasks under high levels of stress. Though the attentional narrowing phenomenon has received much empirical support as the underlying reason for a diminished ability to execute various tasks, other factors were suggested as possible contributors to these debilitative effects. Specifically, proposed was that the influence of

distractors, and the tendency to be distracted when faced with increased activation levels may also contribute to performance decreases, but had not been addressed. Wegner (1994) and others have presented the notion that as stress levels increase, the propensity of the performer to be distracted is enhanced. Though empirical evidence does not exist to support this notion, anecdotal self-report from athletes and athletes and other performers warranted investigation into this area (Moran, 1996). No research done to date in the context of peripheral narrowing had been conducted in which distractors were presented to participants while performing central and peripheral tasks.

Another issue of interest was whether the performance changes that were anticipated to occur under elevated levels of activation were due to changes in psychological affect (e.g., cognitive anxiety), an increase in arousal level, or some combination of both. By examining these variables in the context of the cusp catastrophe model (Hardy & Fazey, 1987), a clearer understanding of them and their affect on attentional processing was delineated.

Third, determined to a certain extent was whether performance changes under higher levels of activation were due to the perceptual alterations in visual selective attention (as indicated by changes in visual search patterns) or other non-perceptual factors (i.e., encoding, response selection) during the information processing of relevant and irrelevant stimuli. As mentioned, one of the areas of controversy regarding the peripheral narrowing phenomenon was with respect to the mechanisms responsible for the lack of effective cue utilization. Indirect support has been provided for both a diminished ability to perceive relevant cues as well as a decrease in the efficiency of later stages of

information processing. Before this study was undertaken, no researchers had used eye movement information to clarify these issues. However, shifts in visual attention from central areas of a display to the periphery, and vice-versa, were reflected in the visual search data obtained in this experiment. Furthermore, information gathered from the use of visual search monitoring equipment was used to shed some light on the question of distraction versus narrowing by indicating whether eye-movement patterns were altered to focus more on distractors while under high levels of stress. A fourth area of significance addressed in this experiment was the effect of elevated activation levels on specific performance variables. In particular, by evaluating performance in terms of a variety of accuracy, speed, and reaction time measures, a more complete understanding of the separate elements of proficiency that are impaired or facilitated was ascertained. As Jones and Hardy (1990) have suggested, the lack off attention to these specific performance variables rendered it difficult, if not impossible, to prescribe interventions to enhance them.

Finally, an attempt was made to surmise whether skill execution was affected in a gradual or more dramatic fashion at higher levels of activation. Although the view of an inverted-U relationship between activation levels and performance is still the most popular conception of the relationship, this investigation provided evidence that perhaps more recent models (such as the cusp catastrophe model) are more accurate in their predictions.

From a more applied point of view, the results of this investigation are expected to benefit both drivers and sports performers. Though merely a simulation, the findings from this investigation give an indication of the manner in which excessive driving demands (such as heavy traffic, being “cut off”, or near accidents) which increase the level of

activation of drivers will affect their attentional abilities. Furthermore, the impact of attentional abilities on the central task of driving the car (accelerating, braking, and steering) as well as the ability to detect and effectively process peripheral information were elaborated.

It is anticipated that many of the results obtained from this study will be generalizable to other dynamic and reactive sport activities that involve the coordination and flexibility of attentional processing between central and peripheral sources of information. By developing a clearer understanding of information processing abilities in these types of environments, it may be possible to derive training simulations to help athletes to maintain focus on the most relevant cues in the performance situation. For instance, Singer, Cauraugh, Chen, Steinberg, Frehlich, and Wang (1994) have shown that it is possible to train attentional parameters to be more in line with expert strategies used in reactive tennis situations. Perhaps this will be possible in tasks in which an anxiety-producing situation is present, such as the high speed driving context of interest in this study.

CHAPTER 2

REVIEW OF LITERATURE

When considering the ability to attend to, process, and react to specific cues in dynamic, highly reactive sport situations in the most efficient and correct manner, issues arise concerning the various attentional and information processing components that either facilitate or impede performance. Specific questions include: How do performers know which cues to attend to? What are the properties of particular cues that make them salient and informative to the participant? What information is extracted from cues as they are attended? What are the separate influences of arousal and anxiety levels on the ability to perform effectively by selecting and processing the most relevant cues at the right time? Do eye movements and other behaviors associated with visual attentional processing change under stressful situations? If so, do changes in attentional shifts and eye movements reflect detrimental or facilitative effects of performance? Are these effects due to a narrowing of the visual field and/or to changes in the ability to mediate the distracting properties of irrelevant stimuli? These are questions that have received little attention in the context of sport and other performance areas and will therefore be investigated in this project.

The influence of an organism's general level of activation is integral to the ability to respond to particular stimuli in an effective and timely manner. The level of activation

is usually described in terms of the performer's state of arousal, which has been defined by Abernethy (1993) as "a physiological state that reflects the energy level or degree of activation of the performer at any particular instant" (p.129). Since the publication of the Yerkes-Dodson (1908) Inverted-U theory, much research has been devoted to understanding the influence of arousal states on the ability to attend to, discriminate, and process information in tasks ranging from simple laboratory reaction time tasks to more applied areas in sport, the military, and industry. Research in which the effects of stress on performance have been investigated have ranged along a continuum from assumed low levels of arousal in vigilance tasks to very high levels of arousal in quickly changing, interactive, dynamic environments or situations in which the perception of threat has been induced.

A concept that received a great deal of attention during the early 1950's was the narrowing of the attentional field as arousal and/or anxiety increased, culminating in the publication of Easterbrook's (1959) article describing the phenomenon. The peripheral narrowing idea has been used extensively to explain changes in performance in a variety of laboratory tasks and has been generalized to other real-world applications. However, in the sport domain, empirical investigation of the peripheral narrowing phenomenon has been sparse. Furthermore, other factors such as the influence of distraction on decision making and information processing capabilities of athletes have been virtually ignored by sport psychology researchers. Similarly, no research has been directed toward assessing these various attentional parameters in the sport of auto racing. However, due to its reliance on speedy decision making and attentional shifts under extreme time constraints

and life-threatening circumstances, auto racing provides the ideal environment in which to assess these factors. Inferences to such situations in other contexts and with other tasks can be made, which is the intent in the present study.

Accordingly, the focus of the following literature review is to critically evaluate the literature that led up to and continued beyond the publication of Easterbrook's (1959) influential work. Also, the separate components of stress will be compared and contrasted, and the interactive influence of these components on attention will be summarized. Furthermore, a justification for examining attentional processing in stressful environments with respect to eye movement parameters will be provided. Finally, an empirical framework will be proposed to evaluate the influence of physiological and cognitive stress on attentional capabilities in a simulated race car driving task.

Stress and Human Performance

Anxiety, arousal, fear, and a variety of other terms that fall under the guise of *stress* have been studied extensively in terms of their influence on performance, individual responses to stressors, and methods of regulating the stress levels of sport performers. The very nature of sport, with its increasing public exposure, the pressures placed on athletes to win from coaches, other athletes, and themselves, the rewards for great performance, and the disappointment from losing, is full of stressful performance situations (Murphy, 1995). Athletes who are able to regulate the stress response and perform in competitive situations in spite of the surrounding pressures inherent in sport are those who will inevitably excel.

However, though the general topic of stress in sport has received much attention from sport psychology researchers, confusion has been proliferated by the fact that many researchers and practitioners use terms such as activation, stress, anxiety, and arousal interchangeably, treating a multidimensional construct in unidimensional ways. Accordingly, before addressing the specific issue of attentional narrowing as a result of stressful circumstances, a discussion of the similarities and differences of these terms must be addressed. Also, a discussion of popular theories developed to describe how performers deal with stress and the theoretical basis for the present investigation will be provided in light of the recently proposed cusp catastrophe model of anxiety and arousal (Fazey & Hardy, 1987).

Stress

Stress is defined as a combination of stimuli or a situation that is perceived as threatening and which causes anxiety (Hackfort & Schwenkmezger, 1993)). Various stressors include external threats, deprivation of primary needs, and performance pressures that can be characterized as both general and sport specific. Selye (1956) described stress based on the principle of equilibrium in which self-regulation is of primary importance. He differentiated stress (a condition to which we are always prone) from the inability to cope with the stress.

A popular cognitive view of anxiety that was heavily influenced by Selye's ideas was forwarded by Lazarus and his colleagues (e.g., Lazarus, 1966; Lazarus & Averill, 1972). Basically, Lazarus viewed anxiety as an emotion with a specific pattern of arousal that corresponds to it and that is influenced by the cognitive appraisal and perception of an

anxiety-producing event. According to this view, all facets of a situation tend to be classified with respect to its significance and the implications of that situation on the person's well-being. Therefore, it is the perception of the event and not the event itself that dictates emotions. Researchers have discovered that, contrary to the medical model of stress, many people view stress and anxiety as challenging, exciting, and beneficial (Lazarus & Folkman, 1984).

These findings prompted the formulation of Kobasa's (1989) Hardy Personality Theory which states that people who are psychologically hardy tend to view stressful situations in a positive way. The specific characteristics of psychologically hardy people are that they (1) are committed to the activity, (2) believe they can control or influence events, and (3) view demands or changes as exciting challenges. Similarly, Smith's (1980) mediational model suggests that the appraisal process creates the psychological reality based on what the individual tells himself or herself about the situation and the ability to cope with it.

Meichenbaum (1985) also suggests that the cognitive appraisal of the individual is what dictates the nature of the interaction with the environment. The meaning the person construes to the event is what shapes the emotional and behavioral response. Similarly, Mahoney and Meyers (1989) postulate that it is not stress that is central to performance but the athlete's expectations, efficacy beliefs, and use of arousal that will determine performance. Therefore, arousal, if perceived as natural is positive but negative anxiety (i.e., worry) is negative. Being aroused does not mean that one will become anxious. Rather, anxiety occurs due to (1) distrust of natural responses, (2) ineffective perceptions

due to previous exposure to modeling of arousal, (3) directly being taught that arousal is bad, and (4) early failure experience while aroused. Support for the notion that it is the perception of the stressful situation that dictates performance is provided by findings that athletes enjoy the "nervousness" associated with competition. Rotella, Lerner, Allyson, and Bean (1990) have shown that precompetitive feelings of high activation are helpful to performance if they are perceived to be natural and provide a sense of readiness rather than concern.

Unfortunately, all athletes, even those perceived as being the best in stressful situations, occasionally "choke" under pressure. Thus, the question remains: How do external and internal stressors manifest themselves in the stress response and how does the stress response affect performance? The rest of the review will be directed toward describing situations in which the performer fails to regulate the stress response appropriately. A justification for continued research in this area will be provided. From a cognitive perspective, then, questions arise concerning how the stress response influences the ability of performers to process information and allocate processing resources to coping with stressful stimuli as well as dealing with task demands and constraints.

Theories of the Stress Response

Controlling the stress response is critical to the ability to perform well. Whether or not cognitive appraisal reflects reality is not necessarily important in terms of the stress response for the simple reason that it only occurs in situations in which self-regulatory skills fail (Carver & Scheier, 1981; Cherry, 1978; Jones, 1990; Lazarus, 1966).

The analysis of stress has its roots in the psychoanalytic conceptualization of the construct. Specifically, Freud (1952) postulated that affect and neurosis are closely related to each other, with affect being related to exogenous arousal and neurosis being related to endogenous arousal. Though not the most popular view of stress today, this does provide a foundation for much of the work done in the psychoanalytic realm and provides the impetus for later cognitive and behavioral approaches to the study of stress.

Mowrer's (1960) learning theory approached stress from a behavioral learning viewpoint involving both classical conditioning and instrumental reinforcement. He suggested that in environments where specific stimuli result in stressful outcomes, the organism would eventually learn to associate the stimulus with the stressful outcome. For instance, if an athlete consistently performs poorly in a specific competition setting, eventually, the simple thought of that setting will elicit an anxious response.

With the cognitive revolution in the late 50's and early 60's, stress (in particular, anxiety) was viewed as an emotion that is triggered by a person's "communicative relationship" with the environment and arose from expectations and appraisals of these situations (Festinger, 1954). Festinger suggested that anxiety control is based on decisions that lead to either direct actions to remove the anxiety-producing stimulus or to avoid it (the approach/avoidance distinction). Three assumptions that formed the basis of Festinger's theory were that: (1) a person who cannot account for arousal will look for something to attribute it to, (2) previous explanations do not cause a need for appraisal, and (3) a person with arousing thoughts but no physiological arousal will not show emotional response and therefore will not be stressed. According to this view, an athlete

that experiences physiological arousal will only choose to exert cognitive processes for interpretation of it if the arousal persists, and is unaccounted for (Hackfort & Schwenkmezger, 1993).

As will be described in depth later, the specific reactions to stress are individually determined. Stress can be manifested in the form of cognitive and somatic anxiety, physiological arousal, loss of self-confidence, panic, and a variety of other forms. Obviously, each of these different responses will have an influence on performance if not regulated appropriately.

The Stress/Performance Relationship

One of the more popular early conceptualizations of the stress/performance relationship was the Hull/Spence Drive Theory (Hull, 1952; Spence & Spence, 1966). According to the theory, level of activation is considered a function of the sum of all of the energetic components affecting an individual at the time of a particular behavior. Furthermore, drive strength is dependent on the emotional reaction that is caused by an aversive stimulus. Thus, people with increased drive levels perform better due to their greater effort, emotion, and motivational need to remove the aversive stimulus. Though an attractive early attempt to explain the stress/performance relationship, empirical testing has suggested that the theory is not generalizable to many situations, especially those requiring fine motor control.

Other popular theories that have attempted to relate stress to performance are the 'optimal zone' theories. Of these, Hanin's (1980) concept of an arousal zone of optimal functioning (ZOF) has received the majority of empirical investigation. Though initially

criticized as a reiteration of the Inverted-U hypothesis (Yerkes-Dodson, 1908) (which will be discussed at length in the next section), it is instead an interindividual account of how arousal affects performance. The attractiveness of the model rests in the fact that it accounts for individual differences, something the Inverted-U is unable to do. A similar theory is Martens' (1987) zone of optimal energy.

Csiksentmihalyi's (1975) concept of a less sport-specific optimal arousal state (or FLOW state) is another attempt to explain the activation of the organism at a level that is most conducive to performing well. The flow state is characterized by a variety of factors including (1) awareness, but not being aware of awareness, (2) focused attention, (3) loss of the ego and self-consciousness, (4) feeling of being in control, and (5) intrinsic reward from performing well. Often athletes refer to the flow state in discussing their best performances and continued research is being directed toward understanding the factors that allow athletes to enter this relaxed state of intense concentration and seemingly effortless ability to perform at the highest levels.

Another related theory to that of the 'optimal states' is Kerr's (1989) Reversal Theory. Based on Apter's (1982) phenomonological theory of motivation, emotion, personality, and psychopathology, Kerr's basic premise is that depending on the metamotivational state in which the athlete is currently involved, there is a combination of arousal and "hedonic tone" (feeling of pleasure) that dictates whether that state will be associated with anxiety, pleasurable excitement, boredom, or relaxation. A discussion of the intricacies of reversal theory is beyond the scope of the current review, but it does

provide a unique way to view the arousal/anxiety/performance relationship and warrants further investigation.

Inverted-U Hypothesis

Of the theories that have been proposed to account for the relationship between stress and performance, perhaps the most influential and misunderstood is Yerkes-Dodson's (1908) Inverted-U hypothesis. The basic premise of the Inverted-U hypothesis (which was generated based on work with animals) is that as arousal increases so does performance until an optimal level is reached. At this point, any increase in arousal level will lead to a gradual deterioration of performance until arousal level is reduced to the optimal level (Yerkes-Dodson, 1908). Unfortunately, sport psychology research has been reluctant to abandon the rather shallow notion of the Inverted-U hypothesis due to the simplistic nature of the theory and its almost universal application. The myths and realities surrounding this controversial theory and the research undertaken that both supports and refutes it will be briefly reviewed in the following section.

It has been postulated that one mediator of the stress/performance relationship is the characteristics of the task. In regard to the influence of task characteristics on the stress/performance relationship (and assuming the Inverted-U relationship of stress to performance), Oxendine (1970, 1984) and Oxendine and Temple (1970) suggested that different types of tasks require different levels of arousal. According to Oxendine, a moderately above resting level of arousal is required for the successful execution of all motor tasks. Also, a low level of arousal is best for tasks involving complex movements,

very fine motor control, steadiness, and concentration. Finally, in gross movements requiring strength, endurance, and speed, a high level of arousal is most beneficial.

Though intuitively appealing, Oxendine's suggestions have been criticized due to their simplicity (Jones, 1990). Jones provides several examples of sport situations where Oxendine's hypotheses do not hold true and cites three primary reasons for their lack of value. First, only one of the three predictions has held up to empirical examination; that relatively lower levels of arousal are most advantageous for complex, highly specialized tasks. Also, his classification system is overly simplified in that entire sports such as basketball which requires extremely diverse arousal states during the course of the game can be categorized in one of the three levels. Finally, Jones (1990) suggests that Oxendine does not consider the cognitive requirements of the skills in favor of focusing on the movement parameters in particular.

Another one of the primary criticisms of the Inverted-U hypothesis is its global nature. It seemingly relies on the notion of a general stress response that influences performance (e.g., Neiss, 1988). Levi (1972) made an early attempt at separating the different components of the stress response by suggesting that both high and low levels of arousal could be experienced as stressful. In this vein, he proposed that an increase in stress would result from the further deviation of the arousal state from the optimal level. However, these ideas have also been criticized and basically dismissed by the newer concepts of the interactionist approach to stress in which individual differences in the perception of the stress response are accounted for, not simply the fact that being underaroused or overaroused causes stress.

Another problem with the Inverted-U description of the stress/performance relationship is that it is a *description* and nothing more (Jones, 1990). No explanation is offered for why performance is impaired when arousal deviates from the optimal level. Though factors such as attentional allocation of resources, attentional narrowing, and hyperdistractibility have been suggested and many have been investigated, the Inverted-U hypothesis specifies none of these as the primary contributor to the decline in performance as arousal deviates from optimal levels. More than likely, it is a combination of these factors that impacts on the ability of the performer to function efficiently and to process information effectively in the stressful environment.

Another criticism that has been levied against the Inverted-U hypothesis is that it does not address specifically how performance is influenced. Rather, the hypothesis merely states that overall capabilities, in a very general sense, are dependent on the level of stress. Obviously, this description is entirely too global and does not explain how such variables as speed of information processing, stimulus detection ability, and response accuracy are affected (Eysenck, 1984). Furthermore, as will be addressed later, the actual shape of the Inverted-U hypothesis has been questioned by those who assert a more dramatic decrease in performance at high levels of anxiety/arousal with a more difficult recovery to high performance levels as anxiety/arousal decreases (Hardy & Fazey, 1987).

It has been suggested that there is virtually *no sound evidence* to support the Inverted-U hypothesis (Hockey, Coles, & Gaillard, 1986; Naatanen, 1973; Neiss, 1988). Perhaps, of the critics of the Inverted-U, Neiss (1988) is the most rabid, calling the empirical evidence in favor if the Inverted-U "psychologically trivial". Other researchers

have been equally adamant regarding its lack of applicability, validity, and credibility, calling it a "catastrophe" and a "myth" (Hardy & Fazey, 1987; King, Stanley, & Burrows, 1987). The criticisms and negative connotations associated with the Inverted-U hypothesis prompted Neiss (1988, 1990) to suggest that the study of arousal in the context of the Inverted-U should be abandoned for the following reasons: (1) it cannot be falsified, (2) it cannot function as a causal hypothesis, (3) it has trivial value if true, and (4) it hinders understanding of individual differences in regard to the stress response.

Others suggest that it merely needs to be reformulated to account for individual differences and to address the underlying mechanisms that specify the facilitative and/or detrimental effects of stress (Anderson, 1990; Hanin, 1980; Martens, 1987). Researchers have addressed such areas as the nature of the task (e.g., Weinberg, Gould, & Jackson, 1985), skill level (e.g., Cox, 1990), and individual differences (e.g., Ebbeck & Weiss, 1988; Hamilton, 1986; Spielberger, 1989) with respect to the Inverted-U hypothesis. However, the understanding of these specific components is only beginning to be surmised.

Perhaps much of the confusion, equivalence of empirical results, and lack of consistency in research findings that has been associated with the Inverted-U can be attributed to the multitude of experimental methods that have been used to examine it and the lack of consistency in differentiating the various components that embody the term "stress". A discussion of the specific components that fall under the guise of "stress" will be presented in the following section.

Stress, Arousal, and Anxiety

As mentioned earlier in the review, stress is characterized by a combination of stimuli or a situation that comprises the circumstance of a person's subjective experiences as threatening and which causes anxiety (Hackfort & Schwenkmezger, 1993). According to this view, stress occurs when one is unable to cope with a particular situation, and it arises due to specific 'constellations' of threatening stimuli. Various stressors include internal and external threats, performance pressures, social threats, and sport-specific circumstances. One of the specific components of stress is anxiety.

Anxiety is an emotion characterized by uncertainty; a state of unoriented activation that is learned through the socialization process and direct exposure to anxiety-producing situations (Sage, 1984)). *Fear*, on the other hand, though similar to anxiety, is characterized by the perception of danger in response to a known threat, is a reflex-like defense, and is logical, self-protective, and adaptive (Hackfort & Schwenkmezger, 1993). According to Cattell and Scheier (1961), fear is a specific reaction while anxiety is caused by anticipatory and imaginative processes. Thus they are based on the degree of specificity and recognizability.

Spielberger (1966, 1972, 1983) defines stress as being closely related to state and trait anxiety. The trait component is exhibited as an acquired behavioral disposition, independent of time, causing the person to perceive a wide range of not very dangerous circumstances as threatening. Conversely, state anxiety refers to subjective, consciously perceived feelings of inadequacy and tension accompanied by an increase in arousal in the autonomic nervous system. These characteristics are influenced by both cognitive and

emotional components in which the person is preoccupied with irrelevant thoughts and eventual subjective excitement when the ego is threatened. Spielberger's Anxiety Theory (1966, 1972) states that those with higher trait anxiety tend to respond to stressful situations with even higher state anxiety. In accordance with this view, studies (e.g., Hackfort & Schwenkmezger, 1989) have indicated that those who exhibited higher trait anxiety reported anxiety as debilitating while those who were not trait anxious reported it as facilitative to performance. Similarly, Martens (1971, 1974) determined that highly anxious persons perform better on some tasks while lower anxious do better on others and that the state anxiety level at the beginning of the learning process depends on the trait anxiety level of the person. Furthermore, there appears to be an unexplored interaction between anxiety level, situation-specific stress stimuli, task difficulty, and situation specific conditions of learning and performance.

Another important distinction must be made between cognitive and somatic anxiety. *Cognitive anxiety* is characterized by a state of worry, the awareness of unpleasant feelings, and concerns about ability to perform and concentrate in a particular environment. Worry is a cognitive process that takes place prior to, during, and after a task and is marked by decreases in faith in the performance, increased concern, social comparison, and fear of failure (Hackfort & Schwenkmezger, 1993). These characteristics of worry may represent cognitive, evaluative processes that are suitable for predicting performance, as high levels of worry tend to lead to lower levels of performance (Martens, Burton, Vealey, Bump, & Smith, 1990).

Conversely, *somatic anxiety* refers to the perceptions of physiological arousal such as shakiness, sweating, HR, respiration, and "butterflies" in the stomach. A synonymous term used to describe somatic anxiety is "emotionality", characterized by affective physiological system changes caused by an increase in arousal level (nervousness, increased HR, etc.) (Zaichkowski & Takenaka, 1993). Furthermore, cognitive and somatic anxiety appear to have different antecedents. Somatic anxiety is elicited by a conditioned response to competitive stimuli while cognitive anxiety is characterized by worry or negative expectations about an impending performance or event. A handful of studies has suggested that there tends to be a negative link between worry and motor performance while there appears to be a positive link between somatic anxiety and performance (e.g., Gould, Weiss, & Weinberg, 1981).

Due to the relevance of *somatic anxiety* to *arousal*, these terms are often used interchangeably. However, there is a clear distinction between the two terms. Somatic anxiety refers to perceptions of physiological states and is, therefore, a psychological characteristic. On the other hand, arousal reflects the natural activity of one's physiology and is therefore a purely physiological construct (Rotella & Lerner, 1993). In this respect, somatic anxiety is influenced by the subjective evaluation and interpretation of arousal. The specific physiological mechanisms that govern arousal level are thought to be regulated by the neurophysiology of the central nervous system, in particular. The four primary structures involved include the cerebral cortex, the reticular formation, the hypothalamus, and the limbic system. The cortex is responsible for cognitive appraisal of incoming stimuli, the reticular formation acts as an organizer with the other components,

the limbic system provides emotional input in the regulation of arousal, and the hypothalamus regulates sympathetic nervous system activity along with the pituitary gland (Zaichkowski & Takenaka, 1993). These upper level control systems exert their influence on the sympathetic nervous system which is primarily responsible for the psychophysiological changes in HR, pupil dilation, respiration rate, blood glucose levels, and other physiological responses.

Though the description of arousal appears straightforward, researchers have conceptualized it in various ways. For instance, Sage (1984) suggests that arousal is synonymous with activation level. Magill (1989) discusses it in a motivational context that serves as an energizing agent to direct behavior to a specific goal. Cox (1990) has defined arousal as alertness while Martens (1987) dislikes the term "arousal" altogether and prefers the term "psychic energy" which serves as the cornerstone of motivation. Based on these current views of arousal, collectively, anxiety appears to be a multidimensional construct that serves as an energizing function of the mind and body and varies along a continuum from sleep to extreme excitement. It contains a general physiological response in which several systems may be activated at once in including HR, sweat gland activity, pupil dilation, and electrical activity of the brain. It also includes behavioral responses (performance) and cognitive processes (appraisal of physiological arousal).

Therefore, in order to gain an accurate assessment of arousal, physiological, behavioral, and cognitive components must be assessed (Borkovec, 1976). It should be emphasized that changes in physiological function are not necessarily indicative of arousal,

and therefore must be accompanied by other measures because any of the physiological components can be altered without impacting the others (Lacey & Lacey, 1958). These issues will be addressed again later in the discussion of multidimensional anxiety theory.

Assessment of the Stress Response

As mentioned, due to the multidimensional nature of the stress response, multilevel assessment is absolutely necessary to gather a better understanding of the influence of the various components of stress on performance. Assessment effectiveness can be maximized through the combination of physiological, behavioral, and cognitive (self-report) measures. Physiological indices of arousal include such measures as skin resistance, pupil dilation, heart rate, electroencephalogram, electrocardiogram, electromyogram, and other biological measures. The advantages of physiological assessments are that they are not tied to verbal statements. Also, they can be used with all types of people and can assess changes in arousal continuously. However, the primary disadvantage is the fact that physiological measures lack high correlations among each other, a condition Lacey and Lacey (1958) referred to as autonomic response stereotype. Also, in most sport contexts, physiological measures will be confounded by other physiological changes due to exercise-induced responses.

Another level of assessment is behavioral. Observation of behavioral change (such as the presence of nervous twitches, vomiting, etc.) can provide an indication of the stress response. Unfortunately, often behavioral observations may be attributed to stress when the actual root of the behavior is not stress-produced. For instance, vomiting could be

due to the flu rather than competitive stress. Therefore, often self-statements are needed to interpret behavioral observations.

Assessment at the cognitive level is usually done through self-report measures. Some of the more popular measures of anxiety include the State-Trait Anxiety Inventory (STAI: Spielberger, Gorsuch, & Luschene, 1970), the Sport Competition Anxiety Test (SCAT: Martens, 1977), and the Competitive State Anxiety Inventory - 2 (CSAI-II: Martens, Burton, Vealey, Bump, & Smith, 1990). It should be mentioned that most cognitive measures of arousal that have been used are those that measure *anxiety,* not arousal. Though much time and effort has been devoted to the development of these self-report measures, Kleine (1990) conducted meta-analyses that indicated only a moderate relationship between various measures of anxiety and performance. Furthermore, his results suggested that the STAI (a non-sport-specific measurement tool) was as good as the SCAT (sport-specific) for predicting performance in sport. Further criticism has been directed toward the SCAT due to the unidimensionality of the instrument (assessing only the cognitive aspects of anxiety) and its bias toward assessment of the frequency of debilitating anxiety while ignoring possibly facilitative aspects.

As mentioned, one of the primary weaknesses of research on stress and more specifically, anxiety, is the lack of multidimensional assessment. The CSAI-2 is more multidimensional in nature as it separates measures of cognitive and somatic anxiety and has been used extensively in sport research. The reliability and validity of the instrument and its ability to measure the multidimensional nature of anxiety is laudable. The next section of the review addresses the multidimensional nature of anxiety and the importance

of obtaining a better understanding of the influence of specific components of anxiety and their influence on performance from both a basic and applied point of view.

Multi-Dimensional Anxiety Theory

Due to recent concern with the lack of usefulness of the Inverted-U model of anxiety and/or arousal, theorists began to search for a better explanation of the stress/performance relationship. Researchers began to attempt to break down the stress response into its various components. These concerns eventually lead to the formation of multidimensional anxiety theory which has also spurred the development of other theories such as Hardy and Fazey's (1987) catastrophe theory. The generation and a general summary of multidimensional anxiety theory follows.

Perhaps the first to attempt a defragmentation of the general stress response were Liebert and Morris (1967), who identified two primary contributing factors to anxiety: Worry and emotionality. In Liebert and Morris's view, worry consisted of cognitive concerns about one's performance while emotionality referred to the autonomic reactions to the performance environment. This initial identification heavily influenced Davidson and Schwartz's (1976) multidimensional model of anxiety. They were the earliest to use the terms "cognitive" and "somatic" anxiety and formulated their theory in the context of clinical applications. Thus, worry has become synonymous with cognitive anxiety and emotionality has become synonymous with somatic anxiety. Cognitive anxiety is typified by the awareness of unpleasant feelings and concerns about ability to perform and to concentrate. Conversely, somatic anxiety is characterized by perceptions of physiological arousal such as shakiness, sweating, HR, respiration, and "butterflies in the stomach".

These general characteristics of the components of anxiety have held up under empirical investigation and appear to be manipulable independently (e.g., Schwartz, Davidson, & Goleman, 1978).

As mentioned, another characteristic of the multidimensional components of anxiety is that they appear to have different antecedents. Somatic anxiety is elicited by a conditioned response to the competitive environment, while cognitive anxiety is characterized by worry or negative expectations. Researchers have consistently shown that somatic anxiety tends to build as the event (or competition) grows nearer and dissipates as performance begins, while cognitive anxiety continually fluctuates as the subjective probability of success varies (Jones & Hardy, 1990; Martens et al., 1990). Martens et al. (1990) found that cognitive anxiety remains stable and high during the period preceding an event while somatic anxiety peaks at the moment just before competition. Likewise, in an earlier study, Spiegler, Morris, and Liebert (1968) reported similar results in the context of test anxiety.

Another means in which cognitive and somatic anxiety differ is with respect to their effects on performance. In accordance with differences in the time course of anxiety onset, somatic anxiety would be expected to have no influence on performance while cognitive anxiety would have a significant influence, due to the ever changing subjective probability of success. Consistent with this prediction, Martens et al. (1990) found that this was the case. However, other studies have shown an Inverted-U relationship of somatic anxiety to performance (Burton, 1988). Furthermore, studies using the time-to-event paradigm have found that cognitive anxiety actually has a positive effect on

performance in the days leading up to a competition (Hardy, 1996). Thus, it appears that rather equivocal results exist on both sides of the argument. Jones and Hardy (1990) interpret the disparity and lack of consistency in findings to the multitude of different paradigms that have been devised and the abundance of analyses that have been applied to reduce the data.

Another problem that exists with respect to multidimensional anxiety theory is the two-dimensional approach used to explaining the effects of somatic and cognitive anxiety on competition. Specifically, the two-dimensional approach in analyzing results tends to neglect the *interaction* of the components of anxiety, treating them independently rather than in combination (Hardy & Fazey, 1987). According to the viewpoint of Hardy and his colleagues, any relatively comprehensive treatment of these components must consider them in an interacting, three-dimensional manner. In an attempt to improve the predictability and structure of the model, therefore, Hardy and Fazey (1987) developed a catastrophe model of anxiety and performance.

A Catastrophe Model of Anxiety

In an effort to advance understanding beyond the multidimensional approach to the study of the effects of anxiety and arousal on performance, Hardy and Fazey (1987) formulated a three-dimensional model of the relationship. Borrowing heavily from Thom (1975) and Zeeman (1976) who originally devised the idea of catastrophes and then applied them to the behavioral sciences, respectively, Hardy and Fazey's (1987) model is closest in form to the cusp catastrophe, one of the seven originally proposed catastrophe models of Thom (1975). Zeeman (1976) borrowed Thom's original ideas and described

the theory by developing a machine to model it. When describing human behavior, however, events are less mechanistic and absolute, requiring the model to be revised such that changes in one variable (i.e., anxiety or arousal) increases the likelihood that the dependent variable (i.e., behavior) will change in a predicted direction.

Of the two independent variables in Hardy and Fazey's (1987) model, anxiety is the "splitting factor", the variable that determines performance levels and ultimately, catastrophes. The roles of cognitive anxiety and physiological arousal were chosen specifically to be able to evaluate testable hypotheses with respect to the anxiety/arousal/performance relationship. Specifically, when cognitive anxiety is low, the model predicts that physiological arousal will influence performance in an inverted-U fashion. However, when physiological arousal is high, such as on the day of competition, high levels of cognitive anxiety will result in lower levels of performance. When physiological arousal is low, such as during the days leading up to competition, higher cognitive anxiety will lead to increases in performance. When cognitive anxiety is high, the effect of physiological arousal depends on how high cognitive anxiety is elevated. Usually the manipulation of anxiety and arousal is carried out through a time-to-event paradigm in which assessments are taken at specified times leading up to a competition setting. For instance, assessments will be taken one week prior, two days prior, and then one hour prior to the competition setting. In this way, the time course of anxiety and arousal can be assessed. In other instances, levels of anxiety and arousal are manipulated through the use of both ego-threatening or other anxiety producing instructional sets and through the use of exercise-induced arousal, respectively.

Testable hypotheses have been generated from the conceptual framework of the original catastrophe model (Fazey & Hardy, 1988). According to the model, physiological arousal changes are not necessarily detrimental or facilitative to performance. However, if physiological arousal is high, it can have catastrophic effects on performance in situations where cognitive anxiety is also high. Another prediction is the hysteresis effect. Due to the splitting effect of cognitive anxiety, under high cognitive anxiety conditions, physiological arousal will have a differential effect on performance when it is increasing as opposed to when it is decreasing. A third prediction is that intermediate levels of achievement are most likely to occur under conditions where cognitive anxiety is high. Finally, Fazey and Hardy (1988) suggest that it is possible to fit statistical models to cusp catastrophes.

One notion that may become obvious in the discussion of the differences in the catastrophe model versus multidimensional anxiety theory is the suggestion that cognitive anxiety can facilitate performance at certain times, especially in the days leading up to competition. This is in direct contrast to most studies of cognitive anxiety that have demonstrated a negative relationship between it and skill execution. With further thought, however, it is obvious that the motivating effects of cognitive anxiety in the days leading up to competition could eventually facilitate achievement capabilities. Also, it should be emphasized that in many of those studies in which a negative relationship has been identified between cognitive anxiety and performance, assessment was made on the day of competition, when physiological arousal can be assumed to be relatively high (Hardy, 1996).

Another obvious feature of the cusp catastrophe model of the anxiety-performance relationship is the choice of physiological arousal rather than somatic anxiety as the normal factor. The primary reason for this choice was based on the notion that it is part of the organism's natural physiological response to anxiety producing situations (Hardy, 1996). The physiological response to performance anxiety is sufficiently well-established to be considered in the context of a generalized response within the competition setting. However, though the physiological response may be reflected in self-reports of the presence of somatic anxiety, the purely physiological index can encompass the individual task requirements, different situations, and other combinations of factors that override reports of somatic anxiety. Furthermore, physiological arousal changes tend to be mirrored by changes of somatic anxiety while the converse is not the case (Fazey & Hardy, 1988; Hardy, 1996; Hardy & Fazey, 1988).

Substantial support has been shown for the cusp catastrophe model of the anxiety performance relationship in seminal investigations of the model by Hardy and his colleagues. Hardy, Parfitt, and Pates (1994) and Parfitt, Hardy, and Pates (1995) conducted two studies to examine the relationship. In the first of their studies, the time-to-event paradigm was implemented to manipulate anxiety independently of physiological arousal in female basketball players and was primarily directed toward examining the hysteresis hypothesis. Physiological arousal was measured by a Polar heart rate monitor (HRM) and cognitive and somatic anxiety were measured with the CSAI-2. The task was a basketball free throw that was performed after completing physiologically arousing exercise. Findings indicated that both cognitive and somatic anxiety were elevated on the

day before the tournament. This was a somewhat different finding as compared with previous studies in which somatic anxiety increases usually only occurred on the day of the significant event. The data with regard to the hysteresis hypothesis were supportive. In general, performance followed a different pathway with respect to heart rate when increasing as opposed to when it was decreasing in conditions of high cognitive anxiety but not in conditions of low cognitive anxiety.

In the second experiment, Parfitt, Hardy, and Pates (1995) examined the generalizability of these findings with women basketball players to male crown green bowlers. The exception in this study was that cognitive anxiety was manipulated through the use of instructional sets rather than through the use of the time-to-event paradigm. The results of the first experiment were replicated in that the three-way interaction between cognitive anxiety, HR, and direction of heart rate change influenced performance in predictable directions.

Another interesting finding that provides support for the cusp catastrophe is a sub-prediction that performance will be most variable under the high and low cognitive anxiety conditions (Hardy, 1996). Specifically, according to the surface of the performance curve, it would be predicted that the highest levels of performance achieved in the high anxiety condition would be higher than the highest levels achieved in the low anxiety condition. Similarly, the lowest levels of performance in the high anxiety condition would be lower than the lowest levels of performance in the low anxiety condition. In fact, these hypotheses were supported in the second study; thereby providing evidence to support the cognitive anxiety component as the splitting factor on the performance surface (Parfitt,

Hardy, & Pates, 1995). Though relatively little work has been done to examine the validity of the cusp catastrophe model, initial results provide evidence to support it and many fruitful areas of research in this area are warranted.

One limitation, however, to the study of anxiety in the context of both catastrophe theory and the other models mentioned above, is a lack of explanation for the performance changes that are noticed in overly stressful situations. One specific cognitive mechanism that has been implicated, but has received limited empirical investigation is the impact of anxiety and arousal on attentional resources. The following section will outline some of the research that has been directed toward examining this relationship.

Anxiety, Arousal, and Attention

One of the critical factors that could contribute to performance changes under anxiety or arousal producing situations is the ability to allocate attentional resources in the appropriate areas and to process information gathered in these areas effectively (Kahneman, 1973; Landers, 1978; Nideffer, 1976, 1989). Evidence seems to suggest an arousal/ performance relationship that is mediated by attentional factors. Support has been found for this notion in both anecdotal and empirical evidence (Nideffer, 1988).

Perhaps the most compelling evidence that favors the notion of a mediating role of attentional processes in the anxiety/arousal/performance relationship is the substantial support provided for the idea of attentional (or peripheral) narrowing. Research has indicated consistent changes in the peripheral acuity of subjects assessed in arousal and/or anxiety producing situations. Various studies have indicated a narrowing of attention that occurs in highly stressful environments, resulting in a tunneling effect where peripheral

cues are selectively attenuated from further processing. Using dual task paradigms, results have shown a facilitative effect in the performance of central tasks with a concomitant decrease in performance of peripheral tasks when performed under a state of increased arousal or anxiety. Literature relevant to the attentional narrowing idea will be reviewed in the following section.

Peripheral Narrowing

The first researchers to address the idea of peripheral narrowing in terms of cue utilization were Bahrick, Fitts, and Rankin (1952). Based on the assumptions that anything to which an organism responds is relevant to performance, and that continuously variable information is more important to interpreting a stimulus than are relatively constant sources, Bahrick et al. (1952) hypothesized that perceptual selectivity would be highly dependent upon cues available. They postulated that objects in the peripheral visual field (as well as those aspects of the central task that are relatively unimportant) would tend to be interpreted as less important than those in the central part of the field. Using a tracking task and several intermittent peripheral tasks, they found that when subjects were offered incentives, performance on the central task was superior to performance on peripheral ones. These results were interpreted as suggesting that performance was influenced by the degree of motivation manipulated by the incentives provided.

Easterbrook (1959) produced the most influential article on the topic of cue utilization based on the findings of Bahrick et al. (1952), and others (e.g., Bruner, Matter, & Papanek, 1955; Callaway & Dembo, 1958; Callaway & Thompson, 1953). Easterbrook indicated that as the level of arousal increased to a certain point, performance on the

central task was facilitated due to the blocking of irrelevant cues in the periphery from being processed. In contrast, as arousal increased, he suggested that performance on tasks requiring less of a central focus deteriorated due to the blocking of relevant cues. Furthermore, performance on central tasks deteriorated if arousal level reached a state in which the funneling effect prohibited attention to relevant cues that were integral to performance of the central task.

Easterbrook (1959) suggested that the degree of facilitation or disruption caused by emotional arousal is dependent on the range of cues required to perform a task effectively. These ideas were consistent with Woodworth's (1938) concept of a "recepto-effector span", an index of the range of cue utilization. The size of the recepto-effector span is related to the number of possible responses permitted following a stimulus, and the influence of warning time on the ability to prepare responses. Based on the work of Bartlett (1950) and Poulton (1957), Easterbrook suggested that in serial task performance, "the effect of increased foreknowledge is that responses can be made in larger units so that inter-response delay times become covert, inter-response junctions are smoothed, net speed increases, precision improves, and the performance may be better described as better integrated" (p.186). Therefore, in tasks that require a large range of cue utilization (larger receptor-effector spans), performance will be facilitated with an increase in the amount of advanced preparation allowed. In relatively simpler tasks, however, requiring reduced cue utilization and attention, a surplus in capacity to attend to and process information exists, permitting the processing of (and distraction due to) irrelevant cues (e.g., Porteus, 1956). In accordance with this view, effective execution on

a variety of serial tasks including paced problem solving, mirror drawing, and tracking, has been shown to decrease in anxious subjects as compared to control groups.

Easterbrook (1959) was insistent on the interdependence of perception and response, based on the premise that a response cannot be made without some type of perception. Similarly, in the absence of a response, it is virtually impossible to determine whether perception occurred. Through this conceptualization, he defined the meaning of a "cue" as occurring when a singular related response has been made to a percept. Likewise, in highly variable situations, containing many cues, a response to a particular cue can be said to have occurred when the response takes the form of the normal response in the absence of other cues. In light of this operationalization of cue meaning, several researchers during the 1950's found that a funneling or reduction of the perceptual field resulted from induced psychosomatic stress (e.g., Callaway & Thompson, 1953; Combs & Taylor, 1952). In most perceptual tasks administered, manipulations causing the range of cue utilization to fall below that required to complete the task resulted in relative decrements in achievement (Eysenck, Granger, & Brengelman, 1957; Granger, 1953). However, it is important to note that the degree of skill deterioration on tasks is highly relevant to task complexity. As Easterbrook wrote,

> For any task, then, provided that initially a certain portion of the cues in use are irrelevant cues (that the task demands something less than the total capacity of the organism), the reduction in range will reduce the proportion of irrelevant cues employed and so improve performance ......When all relevant cues have been excluded, however, (so that now the task demands the total capacity of the

subject), further reduction in the number of cues employed can only effect relevant cues, and proficiency will fall. (p.193)

One may question the effect of learning on the ability to select and process only the most relevant cues in a display. Support for the idea that overlearning improves the ability to select appropriate cues has been provided by Bruner, Matter, and Papanek (1955). In regard to learning, the question of "What makes a cue relevant or irrelevant?" must be answered. In other words, how does a person know what cues to select and what information will be gained from selection of particular cues? It appears that cue relevance is specified by the amount of information obtained from a cue and the task requirements at hand. Thus, cue utilization is not merely a perceptual idea, but one that is mediated by the "cerebral competence of the subject" (Easterbrook, 1959, p.196). Consequently, the ability to select and incorporate the most relevant cues while ignoring irrelevant cues is intricately tied to the intellectual competence of the person who must competently complete various tasks.

Easterbrook's (1959) conceptual contribution spurred much work to investigate the mediating factors that influence the degree of peripheral narrowing, and the related facilitation and inhibition in skill level resulting from this condition. The methodologies used and factors investigated are quite varied. As a result, this review, though somewhat comprehensive, cannot account for all studies that have been related to the concept of peripheral narrowing.

Studies concerning the cue utilization theory were prevalent in the 1960's and 1970's and lent credence to Easterbrook's (1959) ideas. Because much of Easterbrook's

theory is related to the conceptualization of arousal as a driving force which directs behavior in a way to reduce the desire for something, many early researchers investigated the cue utilization theory with this underlying theoretical backdrop. For instance, Eysenck and Willett (1962) classified subjects into high and low drive categories based on whether or not they had passed their entrance examination into a training school. Those who had passed were classified as high-drive subjects, while those who had not were classified as low drive subjects. Findings indicated that performance on a Tsai-Partington Numbers test was significantly greater for subjects characterized by high drive rather than those categorized in the low-drive condition. Though not a direct test of the cue utilization hypothesis, the results do suggest limited performance on this highly visually dependent task by those who were at presumably lower drive levels.

A direct examination of the cue utilization theory was conducted by Agnew and Agnew (1963) who used two different tasks, the Porteus maze and the Stroop Color-Word Interference test. Investigated was whether tasks which demand differing levels of attentional span would be effected differentially by increasing and decreasing stress levels as manipulate through electric shock. Success in the Porteus maze task, one that requires a wide range of cue utilization, was detrimentally influenced by electric shock. However, proficiency in the Stroop color word test, requiring a more narrow range of cue utilization, was facilitated by increased levels of arousal. These results provided substantial evidence for the validity of the cue utilization hypothesis.

A similar study was conducted by Tecce and Happ (1964) in which performance on a card sorting task and the Stroop Color-Word Interference test were assessed while

stress levels were manipulated through electric shock. In this way, both relevant and irrelevant stimuli were presented that would be thought to impede performance of the central sorting task. Similar findings to those of Agnew and Agnew (1963) were obtained in which the shocked subjects performed better on the card sorting task than did a no-shock control group.

Another early study in which the cue utilization hypothesis was examined incorporated a state measure of anxiety as assessed by the Taylor Manifest Anxiety Scale (TMAS: Zaffy & Bruning, 1966). Those participants who scored in the upper and lower 20% of the distribution of TMAS scores were selected for the study. The task consisted of learning 19 multiple choice items with 5 zeros for each 19 choice set. With the presentation of the zeros which had to be identified, either a relevant cue, an irrelevant cue, or no cue was presented. Findings showed that the low anxiety subjects performed worse than the high anxiety subjects, responding to both relevant and irrelevant cues while the high anxiety subjects responded to only the relevant cues, ignoring the irrelevant ones. Follow up experiments using the same task as Zaffy and Bruning (1966) but reducing the items from 19 to 15 and increasing the choices from 5 to 7 provided similar results (Bruning, Capage, Kozuh, Young, & Young, 1968).

In their first experiment, Bruning et al. (1968) manipulated anxiety through the presence or absence of the test administrator, while in the second experiment, anxiety was manipulated by feedback regarding the subject's success and failure. Results in the first experiment replicated the findings of Zaffy and Bruning (1966). However, in Experiment 2, it was determined that the high drive subjects were superior in the irrelevant condition

while the low drive subjects were superior in the relevant cue condition. Because subjects responded in different manners based on their anxiety disposition, results do provide some support for the attentional narrowing idea.

Wachtel (1968) also conducted a study to examine the cue utilization hypothesis. However, his goal was to determine whether the cue utilization tendencies could be altered through offering participants a means of coping with the anxiety. The tasks consisted of a central continuous tracking task while identifying a random presentation of peripheral lights. Performance was based on a combined score of accuracy on the pursuit rotor task as well as reaction time to the peripheral lights. Three groups were tested in which one was a control group, the second group was told that it would receive random shocks that were independent of performance, and the third group was told that the longer it went without a shock, the stronger the shock would be. However, this group was also told that it would not be shocked as long as sufficient achievement was demonstrated. Results indicated that groups 1 and 3 reacted slower to the peripheral stimulus, suggesting that proficiency was impaired under the threat of electric shock, but not if the subjects had a means of escaping it. Thus, once again, it appears that stress affected peripheral task performance while facilitating the central task performance.

Hockey (1970) tested Easterbrook's ideas based on the notion that the differential selectivity effect observed between central and peripheral tasks is based not on the actual location of the stimuli but rather the allocation of priorities to the two tasks. He postulated that the high subjective probability of relevant signals to occur in the central field predisposes subjects to focus attentional scanning of signals to the primary task.

Using the manipulation of noise levels on central and peripheral tasks in which he ensured that all signals were detected (making objective and subjective probabilities identical), Hockey (1970) hypothesized that if a probability mechanism (priority allocation) was working, a greater facilitation of central detections in noise would occur only when the signal distribution was biased toward the center of the display. Attentional changes due to noise were inferred by the latency of response to central and peripheral locations. Support for the probability hypothesis was found. The response latency was faster when signals were biased toward the center of the visual field, but not when probability was equal of the signal being presented in the central or periphery. This explains, in part, that the funneling which occurs is a function of the higher probability of relevant cues occurring in the central area, rather than as a function of the spatial location of the signal.

Bacon (1974), using a signal detection approach (Green & Swets, 1966), assessed the nature of stimulus loss by hypothesizing that there is not necessarily a loss of perceptual sensitivity to peripheral or irrelevant stimuli, rather a shift in the subjective decision criterion to respond to peripheral cues occurs. Due to the inconsistencies reported regarding whether performance on central tasks is enhanced or diminished, Bacon suggested that cues that initially attract less attention will show even less attention devoted to them while those that occupy the primary focus of attention attract an even higher degree of attentional processing.

Using a dual task paradigm, Bacon's (1974) results supported Easterbrook's (1959) hypothesis in that the increase in arousal (induced through electric shock) caused a funneling of attention toward central areas and away from the periphery. More pertinent

to the hypotheses tested, however, it was determined that the decrease in attention devoted to the periphery was, in contrast to the expected result, due to a decrease in sensitivity rather than a shift in the subject's criterion for responding. Furthermore, due to the lack of ability to attend to both tasks as well in the aroused condition, the capacity limitation ideas of Easterbrook (1959) were also supported.

Though obviously laboratory-based and basic in nature, these early studies established significant support for the attentional narrowing idea. Eventually, these ideas were tested in more applied arenas. The less controlled studies and observations which will be summarized in the next section provided practical evidence for the viability of the attentional narrowing idea in actual stress-producing environments.

Applications of Peripheral Narrowing Research

Baddeley (1972) reviewed both anecdotal and empirical evidence of peripheral narrowing in "dangerous environments". Citing such examples as those from military combat observations, Baddeley (1972) provided substantial evidence of the impact of perceptual narrowing on real world situations. For example, he found that in the heat of battle soldiers will use their rifles much less efficiently than in training, the ratio of error to hits in combat increases, and tonnage of bombs needed to destroy a target increases. These are each examples of anecdotal reports that indict the deterioration of ability to use the most relevant cues in dangerous or stressful environments.

Weltman and Egstrom (1966) and Weltman, Smith, and Egstrom (1971) applied the idea of peripheral narrowing to a deep sea diving environment under differing conditions of stress. The experimental conditions consisted of surface testing, shallow

diving in an enclosed tank, diving at ocean depths of 20-25 feet (6-8 m), and simulated decompression dives in a pressure chamber. In general, they found that across conditions, performance was maintained on a centrally located monitoring task, but as stress level increased (i.e., the divers descended to more dangerous depths), attention to peripherally located light stimuli deteriorated. Though intriguing, these results may be contaminated by other extraneous factors such as the increase of nitrogen levels in the blood stream.

Surprisingly, relatively few investigations have been undertaken in sport settings to examine the effects of peripheral narrowing. Landers, Wang, and Courtet (1985) investigated peripheral narrowing with experienced and inexperienced rifle shooters. The central task was a target shooting task while the peripheral task was an auditory detection task. Although there were no differences found in secondary task performance between the experienced and inexperienced shooters, they did find that under high stress conditions, both groups shot worse.

As to other sport situations, two studies were conducted by Williams, Tonymon, and Andersen (1990, 1991) to help substantiate Andersen and Williams' (1988) model of athletic injury. In the model, Andersen and Williams (1988) indicate that a possible predisposition to athletic injuries may be precipitated by elevated levels of life stress, resulting in an inability to attend to peripheral stimuli. Support for this possibility was found in the two studies designed to test the model in which Williams, Tonymon, and Andersen (1990, 1991) found significant decrements in detection of peripheral cues while performing Stroop tasks under stressful conditions.

The work done with regard to attentional narrowing in the sport context was reviewed by Landers (1980). In the review, the Inverted-U in sports was explained using Easterbrook's cue utilization hypothesis. In sport, as with other domains, Landers suggested that performance is proportional to the number of cues utilized. At low arousal levels, there is a surplus of cues, including irrelevant cues that must be dealt with. With increasing anxiety levels, irrelevant stimuli are eliminated before relevant ones. Therefore, according to Landers, perhaps there is a bi-directional, reciprocal causality between arousal and performance in sport. Other theoretical proposals have been forwarded to account for the narrowing phenomenon. These will be reviewed in the next section.

Theoretical Explanations for Peripheral Narrowing

Many theories have been forwarded to explain the consistent reduction in cue utilization during performance of tasks in stressful environments. Easterbrook (1959) proposes that if intensity cannot be discriminated between stimuli, a reduction in the employment of cues results. The reduction in the range of cue utilization can also be explained in the context of both Hull's (1943) Drive theory and the Yerkes-Dodson (1908) Inverted-U theory. In the Hullian sense, an increase in arousal (or drive) increases the stimulus generalization of a particular stimulus, resulting in the application of a trained response to stimuli other than the one of interest. In the Yerkes-Dodson argument, as arousal increases, some cues lose their ability to evoke the proper response, hence increased arousal, to a point, will be beneficial, after which decrements will result.

Easterbrook (1959) also implies that the cue utilization hypothesis fits nicely into Broadbent's (1957) idea of the single channel hypothesis of attentional capacity. Though

less popular than current theories of attention, Broadbent's notion that there exists a single cue channel that will affect processing capabilities elsewhere in the system accommodated the cue utilization hypothesis effectively.

However, the idea can also be supported in the context of more recent capacity/resource models such as proposed by Kahneman (1973) or Wickens (1984). These theories, though opposed with regard to the number of resource pools available, suggest a limit in the resources accessible to attain optimal attention as determined by priorities. In line with this view, one primary feature of high arousal levels is a narrowing of attention because the allocation policy is likely to shift away from the periphery and toward the central area. Thus, the allocation policy is also consistent with the probability results obtained by Hockey (1970).

In summary, it appears as though arousal tends to overload the system, narrowing the range of stimuli that are processed by impairing the memory traces of the stimuli of lesser importance, such that processing can continue to be devoted to the more central cues. It seems that narrowing could be due to both an impairment at the perceptual stage of processing and at the short term memory stage. However, the exact location of impairment has not been clearly identified.

Distraction

An idea that consistently recurs as an explanation for performance changes in both central and peripheral tasks is a narrowing of the attentional beam in which irrelevant cues are somehow filtered from processing, either in the perceptual or encoding stage of analysis. However, virtually no one has assessed the impact of distractors in this context

and the concept of distraction has received very little attention from sport psychology and cognitive psychology researchers, in general. It seems logical, however, that the central task proficiency decrements that eventually occur as stress levels increase could also be explained in the context of distraction.

The lack of research directed toward understanding distraction is surprising considering the imperative need to ignore distractors and focus only on the most critical cues in any performance situation. It is also surprising considering that the concept of distraction was actually addressed by William James as early as 1890. Though many of the ideas of James are being empirically investigated even at the end of the 20th century, distraction continues to be a virtually untapped area of research on attention. Meanwhile, examples of athletes and other performers who have been victimized by distraction are numerous (Moran, 1996). The need to avoid distraction has prompted leading sport psychologists such as Orlick (1990) to suggest that it is one of the most important mental skills required to be successful in sport. Perhaps this is why virtually all mental training skills programs developed by sport psychologists are directed toward maintaining concentration on the task and appropriate cues. Interfering thoughts need to be regulated and irrelevant stimuli ignored.

Brown (1993; as cited by Moran, 1996) defines distraction as situations, events, and circumstances which divert attention from some intended train of thought or from some desired course of action. This definition is somewhat different from James' (1890) original conceptualization of distraction which was more directed toward the description of distracting thoughts and being "scatter-brained". Each of these views of distraction can

be more easily understood if categorized in the context of internal and external types of distractors (Moran, 1996). Internal distractors refer to mental processes that interfere with the ability to maintain attention while external distractors are environmental or situational factors that divert attention from the task at hand. Each of the two types of distraction lead to a wandering of attention which Wegner (1994) has suggested is "not just the weakness of the will in the face of absorbing environmental stimulation ... but rather it is compelled somehow, even required, by the architecture of the mind" (p.3). Wegner (1994) has postulated that because the mind tends to wander, there is an attempt to hold it in place by repeatedly checking in to see whether it has wandered or not. Unfortunately, this results in a Catch-22 because by evaluating, attentional focus is inadvertently drawn to the exact thing that one is trying to ignore. He also suggests that when highly emotional, attentional resources are reduced and the mind is inclined not only to wander away from where it should be attending, but also wanders toward that which we are attempting to ignore.

Effects of distraction. Obviously, the typical effect of distraction is a decrease in performance effectiveness. The most plausible explanation for the decrease in performance when distracted by either external or internal factors is the decrease in available attentional resources for processing relevant cues. This idea is consistent with the limited capacity models of attentional resources proposed in different forms by various attention theorists (e.g., Allport, 1989; Kahneman, 1973; Shiffrin & Schneider, 1977). Because attentional capacity is limited, resources directed toward the processing of distractors reduces available resources for the processing of task-relevant information.

This idea is supported by studies which have shown that distraction effects are greater for complex rather than simple tasks, and that distraction effects are greater as the similarity of distractors to relevant cues increases (Graydon & Eysenck, 1989). As tasks become more complex and distractor similarity increases, the attentional resources needed also increases due to a reduction in the automaticity of cue discrimination. Thus, any increase in distractibility will inevitably reduce the attentional capacity available for the primary task.

Distraction and stress. Though empirical evidence is scarce, many researchers have suggested that increases in emotionality as embodied by stress and the various components that make up stress (i.e., anxiety, worry, arousal) increase susceptibility to distraction. Emotional stress would be classified as an internal distractor as it does not exist except in the mind of the performer; but often internal distraction is caused by the erroneous perception of an external distractor (Anshel, 1995). Numerous examples to support the notion that stress impedes performance due to distraction can be found in verbal accounts and behavioral observations of "choking" in competitive environments. Moran (1994, 1996) provides substantial anecdotal evidence that the impact of anxiety is the absorption of attentional resources which could otherwise be directed toward the relevant task. Baumeister and Showers (1986) indicate that increased worry causes attentional resources to be devoted to task irrelevant cues while self-awareness theorists such as Masters (1992) suggest that under stress, not only is attention absorbed by irrelevant stimuli, but also the performance of normally automated skills becomes less automated as resources begin to be intentionally directed toward the process of the once-

automated movement. Self-awareness, then, interrupts the normally fluid mechanics of the movement and inevitably decreases performance. Finally, Eysenck (1992) has provided empirical evidence that anxiety provokes people to detect stimuli which they fear, usually those that diverts them from attending to relevant information.

Paradoxically, it appears that there are two equally attractive explanations for the decrease in performance that occurs under high levels of stress. On one hand, proponents of the attentional narrowing argument would suggest that under high stress levels (either anxiety or arousal induced), the visual field narrows to block out irrelevant information, and subsequently relevant information as stress continues to increase. On the other hand, proponents of the distraction argument would suggest that actually a widening of the attentional field occurs such that irrelevant or distracting cues receive more attention then when under lower stress levels. Evidently, a controversy exists unless in some way, both mechanisms could be working at the same time. Perhaps, an increase in anxiety and/or arousal results in a narrowing of the attentional field while at the same time, especially at higher levels of stress, increases susceptibility to distraction. Thus, many theories can account for how stress affects attention and the eventual impact of attentional variation on performance, but none address specifically why this phenomenon occurs. By briefly examining research in visual attention, perhaps some clues as to what exactly is happening in these contexts may be surmised.

Visual Attention

It has long been known that there is a direct relationship between human performance capabilities and the informational load as well as the response demands

associated with a particular task (Fitts & Posner, 1967; Hick, 1952; Hyman, 1953). That is, as the level of response uncertainty (informational load) increases, so too does reaction time (RT). More importantly, laboratory research tends to indicate that RT to a single unanticipated visual stimulus is in the order of 180-220 ms, with this delay composed of latencies associated with stimulus detection, response preparation, and neural and muscular activity associated with a simple key press (e.g., Wood, 1983). Given these latencies, there is an apparent discrepancy between the obvious time constraints imposed by complex situations (those dominated by heightened levels of response uncertainty) and the ability of elite performers to routinely select and execute the most appropriate motor response.

Hardware vs. Software Approaches

In an attempt to understand this paradox, researchers have forwarded two competing explanations. The first approach posits that expert performers differ from novices in that they possess advanced psychophysical and mechanical properties of the central nervous system (Abernethy, 1991; Burke, 1972). That is, proponents of this theory believe that experts have much faster overall RT's (simple, choice, and correction times) than do novices, and also possess greater optometric (static, dynamic, and mesopic acuity) and perimetric (horizontal and peripheral vertical range) attributes. In accord with the notion that humans are somewhat genetically programmed to possess these qualities, this perspective has been termed the "hardware" approach of expertise.

Support for the hardware approach, however, has been very limited. Studies by Helsen (1994), McLeod (1987), Starkes (1987), and Starkes and Deakin (1984), in which

expert and novice athletes were compared on a number of laboratory tasks involving visual mechanisms (depth perception, static visual acuity) and processing abilities (simple and choice reaction time tasks) demonstrated no significant differences between the two groups. Thus, it appears as though expertise cannot be explained by a CNS advantage on the part of the expert.

In contrast to the hardware theory of expertise, proponents of the "software" approach argue that experts have a much greater knowledge base of information pertaining to their particular area of expertise. Differences in expert performance as compared to novices is thought to be the result of a cognitive advantage, rather than a physical advantage. For example, it is believed that expert athletes make faster and more appropriate decisions based on acquiring selective attention, anticipation, and pattern recognition strategies associated with their sport (Abernethy, 1991). That is, experts learn to know which cues to focus their attention on in their sport environment, and develop an understanding of the importance of these cues in predicting the nature of future sport related stimuli.

Support for the software approach to expertise has been repeatedly demonstrated in studies assessing decision time and accuracy responses for sport-specific situations (Bard & Fleury, 1976; Starkes, 1987). The same is true for the recognition and recall of structured elements of game situations in sports such as baseball (Hyllegard, 1991; Shank & Haywood, 1987), basketball (Allard & Burnett, 1985; Bard & Fleury, 1981), field hockey (Starkes, 1987), and volleyball (Borgeaud & Abernethy, 1987). Given the vast support for the software approach, the rest of this section will describe the cognitive

elements of visual search that provide a better understanding of visual selective attention capabilities.

Visual Selective Attention

Theeuwes (1994) has defined selective attention as "the process of selecting part of simultaneous sources of information by enhancing aspects of some stimuli and suppressing information from others" (p. 94). Visual selective attention theorists are in agreement that there is primarily a two-stage process of selection: A preattentive stage and an attentive stage. The preattentive stage is thought to be unlimited in capacity and occurs in parallel across the visual display. Conversely, the attentive stage is capacity limited and is serial in nature. Preattentive parallel search has been supported by the notion that in simple search tasks, a flat function exists relating RT to the number of non-target items that are varied (e.g., Egeth, Jonides, & Wall, 1972; Neisser, Novick, & Lazar, 1963). This flat function has been regarded as a pop-out effect (i.e., the non-target items pop-out of the display) and gives support to the notion that operations are carried out in a spatially parallel manner. Thus the three properties of preattentive search are unlimited capacity, independence of strategic control (exogenous, stimulus driven,), and spatial parallelism at various locations. Attentive search is characterized by functions that show a linear increase in RT as the number of non-target items increases. It is serial in nature, usually found in tasks with specific arrangements and in conjunctive search, and is probably capacity limited.

The specific nature of the attentive stage of visual search has been hotly debated by theorists who favor the concept of a late selection approach versus those who favor early

selection. In regard to the notion that the attentive stage is limited in capacity, disagreement exists in regard to where the capacity is limited. Early selection theorists (e.g., Theeuwes, 1994; Treisman, 1988; Treisman & Gelade, 1980; Treisman & Sato, 1990) suggest that perceptual operations can be performed during the attentional stage that cannot be handled by the preattentive stage. Conversely, late selection theorists (e.g., Allport, 1980; Duncan, 1980; Duncan & Humphreys, 1989) say that during the attentive stage, no perceptual operations are completed. Rather they propose that during the attentive stage, selection of one of the competing response tendencies elicited by the multiple stimuli occurs.

The idea of a limited spatial location property to attentive search has also been of issue. Specifically, early selection theorists have suggested that there is serial inspection of each item; a notion that is in line with several metaphors that have been forwarded to describe visual selective attention such as the spotlight (Posner, 1980; Treisman, 1988) and the zoom lens (Treisman & Gormican, 1988) which will be described later. The late selection theorists, on the other hand, do not allocate a special role to spatial attention.

Different types of search tasks have been used in an attempt to better understand the covert processes that distinguish the two stages and elements of the stages. The most popular of these tasks have been those characterized as primitive features and conjunctive features. In searches involving primitive features, Treisman and her colleagues (e.g., Treisman, 1988; Treisman & Gelade, 1980) have provided an abundance of evidence that these tasks can be carried out preattentively, exhibiting flat search functions which are the result of the popping-out of the most significant features. In these types of tasks,

information does not need to be passed to the second stage because it is automatically selected and there are no attentional limitations.

As mentioned, a special role for spatial attention has been advocated by those in the early selection camp (e.g., Broadbent, 1982; Hoffman, 1986) to account for findings in which items with unique attributes have not been shown to pop-out when they were irrelevant to the task. This notion also contradicts the idea that top-down control maintains gaze until it comes close to a conspicuous object, and then bottom-up control takes over (e.g., Engel, 1977). Thus, spatial attention may not strictly adhere to the constraints of other types of primitive search tasks. These concepts support for the zoom lens metaphor of spatial attention in that people may intentionally vary the distribution of attention in the visual field (Eriksen & Yeh, 1985). In this case, search for the target proceeds serially, omitting the need for the preattentive stage period. This is in line with a series of studies by Eriksen and his colleagues in which it was shown that non-target items may have a detrimental effect if they are spatially close to the target but have no effect when they are further away. As will be seen later, the idea that attentive search is serial is also an important factor in being able to infer that the line of sight coincides with attention.

Conjunctive feature search tends to show a linearly increasing relationship between the number of different features in the task, and whether the target is absent or present in the display. According to the early selection account, the reason this occurs is due to the need for serial search rather than parallel operations only. However, under certain circumstances such as relatively large displays or search for some particular attributes (depth, movement), search functions become relatively flat (Pashler, 1987; Wolfe, Cave, &

Franzel, 1989). These results can all be accounted for however, by the revised FIT which incorporates some top-down mechanisms in conjunctive search so that non-targets (even though conjunctive) which are very dissimilar to the target do not have the same probability of entering into the attentive stage as do those that are similar.

Stages of visual search. As mentioned, the visual search process consists of two distinct stages (Jonides, 1981). The first of these, the preattentive stage, involves unlimited capacity in which visual information from sensory receptors is held in a rapidly decaying visual sensory store. The literal representation of this briefly held information is labeled "the icon" (Neisser, 1967). This stage of visual search is thought to be automatic, with parallel processing of information, and demonstrates crude feature analysis or detection.

The second stage of visual search, termed the focal or attention demanding stage, refers to the process through which selected items in the iconic store are subjected to a more detailed analysis (Jonides, 1981: Remington & Pierce, 1984; Yarbus, 1967). The concept of selective attention in this context focuses on the determination and passage of specific icons from the preattentive stage to the focal stage. It is in this focal stage that only those cues (icons) in the sport environment that are deemed pertinent will be attended to and used by the athlete.

The process of selecting and processing information from only specific aspects of an entire visual display entails both overt visual orienting and covert mechanisms that occur during eye fixations. Overt visual orienting includes the movement of the eyes and head to focus on a particular spatial location. Both top-down (cognitively driven) and

bottom-up (stimulus driven) processes control the 'macrostructure' of the scanpath (Levy-Schoen, 1981), or where the visual receptors are focused. Covert orienting mechanisms are unseen processors that occur within the attention allocation resources of the brain and are also influenced by both top-down and bottom-up control (e.g., Posner & Cohen, 1984).

Temporal aspects. Though covert orienting mechanisms are, by definition hidden, studies of the covert measures of visual orienting have been reported for the past 20 years based on the cost-benefit paradigm developed by Posner and Snyder (1975) and Posner (1978, 1980) to investigate mental chronometry; the time course of information processing. Much work in this area led to the conclusion that reaction time decreases give the perceiver a head start in shifting attention to the target's location. However, questions arose regarding the effect of location cueing as being related to perceptual sensitivity changes or changes in the observer's response criterion. Using SDT paradigms, results have indicated that the benefit occurs mainly through a change in the perceptual sensitivity (e.g., Downing, 1988). These results have further been substantiated by overt measures of mental chronometry.

Specifically, Saitoh and Okazaki (1990) examined the temporal structure of visual processing while performing a digit string search and matching task in an effort to decompose the stages of reaction time. The time used to encode and memorize the standard digit string increased linearly with each addition to the digit string. Also, it was found that the entire visual search time and RT was associated more with the number of eye fixations rather than the duration of the fixations. This provides support for the idea

that each shift of eye fixation provides a shift in visual attention as well and that the ability to measure the chronometry of information processing can be accomplished through the study of eye movements.

Though the results obtained by Saitoh and Okazaki (1990) are encouraging, many questions have been raised regarding the ability to infer visual attention shifts from eye movements (Klien, 1994; Viviani, 1990). Attempts to clarify this issue have typically involved determining whether saccadic eye-movements can be made without concomitant eye-movements to the location. As mentioned, when highly salient aspects of the display exist, stimulus driven (bottom-up) control takes over (Engel, 1971, 1974, 1977). Cognitive control (top-down) of the scanpath is most evident when a particular aspect of the display is of interest. Goal driven visual search strategies are produced on the basis of cognitive control while stimulus driven responses appear to be elicited by the stimuli themselves and take on the properties of reflexive shifts to the visual field (Yantis & Jonides, 1984). Most research has indicated that while there appears to be a close relationship between stimulus driven saccades and attentional shifts, less convincing evidence exists for the validity of inferring attentional shifts from goal driven initiation.

Research indicates that in the case of stimulus driven saccades, the shift of attention occurs before the initiation of the saccade (Wright & Ward, 1994). In their work looking at express saccades, Fischer and Weber (1993) have shown that attention must first be disengaged from the fixation point at the origin prior to target onset. Posner accounted for these criticisms through an elaborative account of the disengage, shift, re-engage sequence that is probably mediated by activity in the posterior parietal cortex, the

superior colliculus, and the pulvinar region of the thalamus (Posner, Peterson, Fox, & Raichle, 1988). However, even in this description, most data were gathered from stimulus driven rather than goal driven attentional shifts. An in-depth discussion of the benefits and criticisms directed toward inferring attentional processing from eye-movement recording devices will be provided in the following sections of the review.

Metaphors of Visual Attention

Though overt mechanisms of visual selective attention are relatively simple to observe, covert attentional shifts are much more difficult to ascertain. As a result, much debate surrounds the ability to infer cognitive processing from overt observations. Due to the inability to precisely describe the association between line of fixation and attentional processing, several different models have been posed to account for the psychological mechanisms underlying attentional shifts. First, movement models suggest that the focus of attention is shifted from one location to another in an analog or discrete manner (the spotlight metaphor, e.g., Posner, 1980). Another popular metaphor is focusing models which suggest that attentional focus can change from a broader, more diffuse state, then back to a finer, more concentrated state at the destination of the shift (the zoom lens idea, Eriksen & St. James, 1986). Finally, resource distribution models postulate an attentional alignment process that does not involve a movement or a focusing component (Laberge & Brown, 1989). Investigations of each of these models have provided data to support them. However, as will be addressed later, Wright and Ward (1994) suggest that the reason for many discrepancies is the use of a variety of experimental paradigms, tasks, and cueing mechanisms.

The primary question that arises from the debate is whether or not the line of sight is independent of selective attention shifts. The evidence described so far in reference to the stages of processing has been gleaned primarily from studies in which line of sight is inferred from RT and other indirect measures of fixation location. However, much research has been completed with eye-movement recording devices to determine precisely when and where attention shifts during information processing of visual stimuli.

Eye-Movement Recording

The ability to infer attentional shifts from eye movements was first investigated by Helmholtz in the 19th century when he discovered that he could shift his point of gaze to illuminated letters before his actual attention shifted there (the latency of a normal saccade is approximately 220 ms (Fischer & Weber, 1993). James (1890) described attentional shifts as being under involuntary or voluntary control which was the genesis for the study of exogenous (bottom-up) versus endogenous (top-down) processing. However, much research in the area was not possible until the 1970's with the advent of sophisticated eye monitoring equipment. Even with the additional data acquired through eye movement recording devices, researchers have been unable to provide indisputable evidence for the notion that the line of sight coincides with the line of attention.

While the visual search paradigm would appear to be a fruitful means of assessing selective attention strategies, it is not without criticism. Before concluding this section on visual search, it is necessary to discuss some of the limitations and potential problems that currently exist in eye movement recording research. These concerns are reflected in both

the assumptions of selective visual attention theory, and in the eye movement recording techniques themselves (Abernethy, 1988; Viviani, 1990).

According to Abernethy (1988), the first major limitation of eye movement recording lies in the assumption that visual search orientation is reflective of actual allocation of attention. That is, visual fixation and attention are one in the same (where one looks is where one attends). This notion, however, has been refuted by Remington (1980) and Remington and Pierce (1984), who demonstrated that attention can be allocated to areas other than the foveal fixation point. Indeed, attention can be allocated to areas in peripheral vision, a mode that cannot be measured with current visual search equipment (Buckholz, Martinelli, & Hewey, 1993; Davids, 1987).

A second limitation of current visual search recording involves the high trial-to-trial variability that is evident in the literature (Abernethy, 1988). These variable patterns make reliable conclusions about the relevance of specific visual cues difficult. Related to this limitation is the fact that the majority of studies include relatively low sample sizes (often $\underline{n} = 6$ or 8), thus causing internal and external validity concerns.

A third, and perhaps most important, limitation of eye movement recording focuses on the issue of visual orientation and information pick-up. As Abernethy (1988) notes, merely "looking" at visual information does not necessarily equate with "seeing" (or comprehending) this information. Thus, a person may fixate upon pertinent cues in the visual array, but there is no guarantee that he or she is actually attending to or utilizing these cues. In order to empirically determine whether one is actually "picking-up" and using the cues available in the visual field, the technique of cue occlusion has been used.

Like Abernethy, Viviani (1990) addresses many criticisms directed toward the use of eye movement recording devices and the study of visual search to understand underlying cognitions. The main question he poses is, "What can we learn from eye movement data about the perceptual and cognitive processes involved in the exploration of the visual world?" (p.353). Viviani suggests that the use of eye movement research should be a good paradigm based on the following factors: (1) the instrumentation and procedures have become standardized, (2) the information processing approach supplies the intellectual scaffolding for the research, and (3) the central dogma provides much motivation for work in the area. The 'central dogma' which Viviani refers to is the notion that "exploratory eye movements can, at the very least be considered as tags or experimentally accessible quantities that scientists can observe to understand underlying processes of cognition." (p. 354). Viviani goes on to point out three primary reasons why the dogma may not be accurate and cites several lines of research that point to independence between eye movements and cognitive activities (Fisher, Karsh, Breitenbach, & Barnette, 1983; Teichner, Lemaster, & Kinney, 1981)

First of all, according to Viviani (1990), it is obvious that eye movements move in sequential order, representing strictly serial behavior. Therefore, to posit a close connection or dependence between eye movements and cognition, one must assume that the behavior viewed is unfolding in sequential order. This, however, is not the case for all activities as is suggested by parallel processing models (e.g., Rumelhart & McClelland, 1986). The central dogma would be valid of it was known that a given process unfolds sequentially. However, it is false whenever several concurrent processes can be

suspected, unless a theory is developed that describes how eye movements reflect these processes.

Second, similar to Abernethy (1988), Viviani (1990) argues that there is little evidence to suggest that attention coincides with the line of site. He uses examples such as Posner and Cohen's (1984) and Posner's (1980) work to support the notion that under appropriate pre-cueing conditions, visual attention can be directed almost anywhere in the visual field, regardless of the line of sight. He also criticizes the use of static skills in the sense that most laboratory tasks may not even produce results that are useful in predicting eye movements during viewing of such dynamic situations as in a soccer game.

Third, Viviani (1990) says that even if the previous two statements can be assumed to be true, it is difficult to identify the conditions in which it is proper to assume that the sequence of operations actually conveys information. The problem with this point is that information is not in the visual field until the image is able to eliminate a prior uncertainty. Thus, the amount of information required depends on the probabilities of various alternatives. Support has been found for the notion that eye movements tend to cluster around areas of high informativeness (Antes, 1974: based on fixation clusters around corners) and this can be taken to support the central dogma. However, Viviani disagrees with this viewpoint, arguing that the most informative areas of the display are not always those that are most salient.

According to Viviani (1990), three cognitive operations are inescapable when exploring the world to solve a problem. These include (1) activation of a set of a priori beliefs about the possible states of the world, (2) breaking up the complex, holistic

hypothesis that normally regulates interactions with the world into hierarchy of simpler alternatives, and (3) translating these alternatives into a sequence of locations in visual space that will likely disambiguate each alternative. Though these criteria appear to be valid primarily in situations where eye movements are information driven, goal-directed behaviors, rather than simple stimulus driven percepts. If in fact, the specific search path is stimulus driven rather than goal driven, much of Viviani's arguments can be invalidated.

Most visual search researchers will agree that there are three processes that occur within the 300 ms of a typical fixation. These include an analysis of the stimulus in the visual field, a sampling of the periphery, and a planning of the next saccade. Of these three processes, analysis of the stimulus in the visual field is the most important activity during the fixation and the duration is said to reflect the load of cognitive processing (the Process-Monitoring idea: Just & Carpenter, 1980). The next saccade cannot be initiated until the information has been processed from the last one (Vaughan, 1982). A strong body of knowledge regarding reading fixations has been developed through the work of Just and Carpenter (1976, 1980). These studies have tended to show support for the Process-Monitoring idea. However, there is some evidence that the Process-Monitoring idea may not be accurate based on the finding that near normal reading remains possible even when the experimenter controls reading rate (Potter, Kroll, & Harris, 1980).

Other evidence that the line of sight coincides, at least somewhat, with the shift of visual attention, is provided by investigations of the buffer capabilities of the brain and whether, in fact, buffering is a method by which visual information is coordinated and analyzed. As Potter (1983) suggests, the beneficial effects of imposing buffers between

the eye and the mind would be paid for in terms of an ability to infer mental events from eye movement data, as these buffers would decouple the two processes. In fact, the very purpose of the buffers would be to introduce some degree of uncoupling between stimuli and their central effects (Potter, 1983). Potter has proposed the existence of an integrative visual buffer where information from successive fixations is pasted together to provide a coherent alignment of individual fixations, but has found little support for it. Also, O'Regan and Levy-Schoen (1983) believe that the coding of information from the retina may be more semantic rather than analog but, like Potter's work, evidence for this idea has not surfaced.

Scanpath recording sequences have also contributed some support for the central dogma. Jacobs (1986) and others have provided evidence that each saccade brings the eye to a zone where new information can be gathered. However, once again, most evidence from scan path observations can only be used as support for the stimulus driven properties of eye movements.

Based on the evidence provided on both sides of the argument, it appears that weaker versions (i.e., those that do not assume direct relationships, but some sort of association between eye movement and attention) of the central dogma stand a better chance of being upheld than does the strong one (Viviani, 1990). Yarbus's (1967) suggestion that eye movements reflect human thought processes was immediately embraced. However, this was based on purely stimulus driven information cues. Antes (1974) has postulated a weaker version of the dogma, stating that there may be a relationship between the distribution of fixations and the informativeness of a scene. As

Viviani pointed out, however, the informativeness of a scene is difficult to quantify. Once again, reaching beyond the stimulus driven nature of eye movement research is difficult based on the informativeness dilemma.

Though the debate between those who accept the central dogma and those who do not continues and remains unresolved, much research has been conducted to examine fixation patterns of participants in a variety of experimental tasks. In the following sections, some of these studies will be elaborated, especially those concerned with examining fixation patterns of those in driving and dynamic sport-related activities that require quick decisions and rapid attentional shifts.

Visual Attention and Driving

Of all the psychomotor skills that have been researched in terms of the role of visual selective and divided attention, perhaps the one that is most globally relevant and that demands constant monitoring of both central and peripheral information is driving an automobile. Many studies have been undertaken on the role of attention and the visual processing that influences the ability of drivers to consistently process task-relevant information and ignore interrupting or distracting stimuli in order to maneuver and maintain control over motor vehicles. The focus of this section of the review will be to summarize a variety of relevant literature that has been dedicated to understanding the driver as an information processor. Also, a rationale for the investigation of peripheral narrowing in the driving context will be provided.

While driving (as with other psychomotor tasks) there is a limited capacity of attentional resources that can be devoted to an almost infinite number of stimuli at any point of time. The mind has adapted in a way that many functions of the driving task are accomplished virtually automatically (some more than others) such that in many cases drivers can transport themselves from one place to another without even remembering how they got there or what critical pieces of information they may have noticed along the way. However, as the task of driving becomes more complex due to decreased visibility, bad weather, heavy traffic, mechanical malfunction, sudden unexpected obstacles, fatigue, and other factors, the automaticity of driving becomes less instinctive and demands more attentional resources. In these conditions, drivers may experience information overload and may be more likely to place themselves in possibly risky situations.

During normal driving, the driver tends to focus on the central task of keeping the vehicle "on the straight and narrow" so to speak, maintaining control of the vehicle based on the constraints of the driving environment (e.g., speed limits, lane markers, etc.). However, when an object or event that is not in the central (or foveal) field of vision, the eyes are normally moved from the central task to focus more directly on the information that has been attended to in the periphery. Based on the information provided by the newly attended stimulus, a decision must be made regarding whether or not to change driving behavior. These alterations occur both in serial and in parallel depending on the specific situation presented (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). To make matters more complicated, all of these processes are often limited by extremely restrictive temporal constraints (Shinar, 1978).

Level and Distribution of Attention

It has been estimated that approximately 45% of all driving accidents could have been prevented if the driver had attended to critical events before the accident occurrence (Shinar, 1978). Thus, it is obvious that the need to pay attention to critical signs, speed limits, obstacles, and the like, is central to operating a motor vehicle effectively and safely. Shinar (1978) suggests that the two primary characteristics of attention that influence an ability to perform the driving task effectively are the level and distribution of attention.

Level of attention. During normal driving, the level or degree of attention that is distributed to the task is a function of the external environment and its demands and one's internal state of arousal. In situations that are not demanding (e.g., when there is little traffic, weather conditions are ideal, and no time constraints), the primary goal of the driving task is to remain at an activation level high enough that the proper amount of attention is devoted to the task. However, it appears that often this may be more difficult than it seems as is evidenced by the number of incidences in which drivers fail to attend to critical cues and, in extreme cases, actually doze while driving.

The opposite is the case when demands are excessive such as when driving conditions are highly variable (e.g., curvy roads, rain, fog), traffic is heavy, and the driver is in a hurry, trying to reach the destination point in a limited amount of time. In cases such as these, the goal is to remain at a relatively lower and stable level of activation to be able to respond in an effective manner to the demands of the task. Thus, the amount of attention that must be allocated to driving is a direct function of the demands placed on drivers in the particular environments in which they are placed. In accordance with this

view, studies have shown that, in normal driving conditions where demands are few, spare attentional capacity to perform other tasks, irrelevant to the driving situation, exists (e.g., Brown, 1965; Robinson, 1975). A clear example of this ability is being able to carry on in-depth conversations with passengers, even to the extent of being able to look at the other person for an extended period of time, while maintaining satisfactory driving parameters. In this way, the driver can be seen as an information processor who attempts to reduce the processing demands of the driving task to allocate attentional resources to other, more interesting tasks (Shinar, 1978).

The other component of the information processing demands placed on the driver is the amount of risk the driver is willing to tolerate while diverting attention from the central driving task. Research has indicated that the content of a particular road sign has a an influence on whether or not it is recalled, and recall depends on the relevance of the sign to the perception of risk involved in discarding the message. Johanssen and Rumar (1966) found that, in general, the perception of road signs is quite low, but that signs such as speed limit signs were more readily recalled than other signs (such as pedestrian crossing and other general warning signs). In order to recall a speed limit sign or a general warning sign, the meaning of the sign must first be encoded and interpreted. However, when asked to recall the signs passed, Johanssen and Rumar (1966) found that warning signs were not recalled near as often as were speed limit signs. These results suggest that after perceiving the sign and perceiving it as unimportant, the content of the sign is possibly immediately discarded in favor of more relevant signs. Thus, the amount of

processing allocated to the driving task appears to be a function of the subjective importance of the signs.

Shinar (1978) suggests that the spare capacity that is not used under normal driving is reserved to deal with other more demanding situations. A good example of this is passing another vehicle on a two-lane roadway. As Shinar explains, "the release of tension upon completion of the pass can actually be felt" (p. 75). Therefore, it appears that this is an adaptive function and the ability to adapt is facilitated by experience.

Distribution of attention. The other important aspect of attention that influences driving performance is the distribution of attention. As mentioned, though a variety of different analogies have been proposed to explain the breadth of attention, some of the more popular views include the spotlight view (Posner, 1980), and the zoom lens metaphor (Eriksen & St. James, 1986; Erikson & Yeh, 1985).

Regardless of the view of attention that is adopted, researchers would agree that attention can be selectively moved from one spot to another, giving rise to two important concepts when discussing the distribution of attention: Divided attention and selective attention. Divided attention refers to the ability to allocate resources to various objects of interest while selective attention refers to our ability to select the single most important aspects or objects of the display and direct our attention to those areas while ignoring any other competing stimuli (e.g., Cherry, 1953). As is evident, both divided and selective attention are important in the driving environment. While people may choose to selectively focus most attentional resources on the central task of driving, resources must be allocated to the periphery in order to perceive input that is critical to driving the car

effectively and minimizing accidents. Correspondingly, researchers have shown, using both visual and auditory selective attention tasks, that there is a limit to the information processing resources that exists beyond the sensory level, in which both inputs compete for the same limited resources (Kahneman, 1973; Kahneman, Ben-Ishai, & Lotan, 1973; Mihal & Barrett, 1976). With experience, the ability to divide attention increases due to the automaticity of the driving task itself, leaving more resources available to deal with competing stimuli (Logan, 1992).

Visual Search and Driving

Driving capabilities are influenced to a great degree by how well the driver's vision is adapted to the task. Much confusion exists regarding the type of visual capabilities that should be required for licensure, and the confusion primarily surrounds the issue of dynamic versus static visual acuity. Although most driving tests are strictly static in nature, the ability to navigate effectively and safely down the road is dependent upon not only static visual acuity but also dynamic visual acuity in both the central and peripheral visual fields (Shinar, 1978). This may explain why most studies that have examined the correlation of static visual acuity to driving performance have yielded rather inconclusive data with regard to this relationship. On the other hand, researchers who have assessed the relationship of dynamic visual acuity to accident rates have shown (though admittedly not consistently) dynamic visual acuity to be more related to performance than traditional static measures. Along these lines, drivers who are slower in responding to peripheral targets tend to be more likely involved in accidents, and these accidents tend to be more right angle accidents rather than rear end or head on collisions (Shinar, Mayer, & Treat,

1975). Consequently, research efforts are being directed toward understanding, more specifically the type of visual acuity that is most relevant to driving performance rather than simple static visual acuity.

Early research. In addition to issues of visual acuity, further questions exist regarding the ability to selectively attend to and utilize the most critical cues in the driving environment and the ability of drivers to shift attention to both focal and peripheral areas of the display. One way to assess these factors is through learning more about the visual search patterns exhibited by drivers. Though there are inherent limitations in drawing conclusions about visual attention from simply analyzing visual search patterns, most researchers would agree that even if the "central dogma" is only partially true, much can be learned from observing eye movements and inferring cognitive processes from these observations.

With respect to driving, questions arise such as: Where does the driver tend to focus attention most of the time? What are the informative and critical cues that must be attended to drive effectively? How can we maximize the information gained from fixating on the most informative and relevant cues? Shinar (1978) suggests that both internal and external mechanisms govern how visual selective attention operates in the driving environment. External factors are crucial when something in the periphery is deemed worthy of a fixation to the peripheral area while internal factors refer to our expectations of the driving stimuli with regard to where the most informative cues will occur. Though Shinar (1978) admits that the eye-mind connection may not always be true, he also

suggests that it is appropriate under stressful driving situations in which the attentional resources of the driver become more restricted and processing is more serial in nature.

In order to examine, more closely, the relationship between eye movements and driving performance, one must first understand how to describe the driver's visual world. The visual display of the driver can be described in terms of the degrees from a chosen center of the display. The point chosen is usually the *focus of expansion,* the area where the two edge lines of the road appear to converge and the point at which the road appears to expand outward from the center. Rockwell (1972), after almost a decade of study of the eye movements of drivers, concluded that approximately 90% of all fixations while driving occur within $\pm$ 4 degrees from the focus of expansion and that most eye fixations last between 100 and 350 ms in duration. Thus, it appears that drivers adopt an adaptive strategy in which information appearing in the roadway can be identified and processed with the greatest speed. Of secondary importance, however, is that the driver must rely on peripheral vision to account for potentially critical stimuli that do occur in the periphery.

A second way to account for driver's eye movement behavior is through assessment of the time spent viewing various stimuli that appear in the visual display. For example, Mourant, Rockwell, and Rackoff (1969) found that, during open road driving, 50% of the time was spent looking straight ahead, 20-27% was spent looking at scenery to the right and left of the car, and the rest of the time was spent looking at other vehicles, bridges, and the like. Interestingly, only about 2% of the time was spent looking at lane markers or to areas of the road surface near the car. Thus, it appears that much

information such as lane position and direction is assessed through peripheral vision. In driving situations where the demands are higher, such as when following another car, the location of visual fixation as well as the compactness of the fixation area changes significantly. In general, fixations become closer to the car and more compact, and fewer fixations are directed away from the roadway when following another car (Mourant et al., 1969).

Another variable that has been investigated with respect to eye movements is the actual geometry of the roadway. Research has indicated that visual search patterns are different on curved roads rather than on straight-aways due to the change in the focus of expansion (Shinar, McDowell, & Rockwell, 1977). Specifically, it appears that when negotiating a curved roadway, subjects tend to fixate back and forth between the edge markings immediately in front of the car, and the end of the road ahead. This could be due to the fact that on a curved road the focus of expansion is somewhere off the road way itself, and also due to the added importance of lane markings due to the necessity of making larger steering corrections to keep the car in the lane. These results prompted Shinar (1978) to suggest that "The drivers information processing capacity is severely limited so that, when under stress, at any one time the driver can attend to *either* the directional cues (end of the road up ahead) *or* the lateral positioning cues (edge markings close to the car) but not to both simultaneously" (p. 91). One can assume that by "attend", Shinar is referring to focal vision rather than peripheral input.

Another factor that can influence where drivers attend is their experience level. Though we consider the act of driving a car a relatively easy task due to the amount of

practice that most adults have with it, there are approximately 1500 perceptual motor tasks that must be mastered in order to drive an automobile safely on the roadway (Shinar, 1978). The importance of mastering mechanical skills such as accelerating, braking, shifting gears, and others, is readily obvious. However, perhaps a more subtle group of skills that must also be mastered includes perceptual skills (i.e., information gathering skills). Though these skills, like the mechanical ones, become automated with practice, research by Mourant and Rockwell (1972) suggests that the "looking" part of the perceptual motor tasks must also be learned.

Research has shown that in general, novice drivers tend to miss significantly more signs, are involved in more accidents due to improper directional control, sample their mirrors less, and look closer to the front of the vehicle, when compared to experienced drivers (Shinar, McDonald, & Treat, 1977; Summala & Naatanen, 1974). This ineffectiveness of the visual search strategy employed by novice drivers is partly due to their inability to use peripheral vision efficiently, thus requiring constant monitoring of lane position and closer fixation of focal vision to the car than is the case for experienced drivers. The lack of ability of novices to use peripheral vision effectively, may, in fact be due to the highly stressful nature of the driving task for them, and the resulting narrowing and/or distractibility in the visual field.

Experience may not be the best predictor of accident rates; however, when considering results of Williams and O'Neill (1974) who found that experienced race car drivers are involved with more accidents and violations than are "normal" drivers. However, this may be due to the perception of risk and the change associated with

experience such that many of the benefits accrued from experience are offset by risky behavior that is deemed appropriate (Naatanen & Summala, 1976).

Recent research. Recent research has been directed toward understanding more fully the ability of drivers to extract meaningful information from targets along the roadway. In particular, many studies have been done on the demands of the external environment while driving, such as the perception and processing of road signs in order to aid road developers in facilitating the identification of signs, and, thereby, reducing the number of accidents due to lack of perception and good decision making.

Hughes and Cole (1988) investigated the effect of attentional demands on eye movement behavior during simulated road driving. They attempted to assess how a driver's performance was effected by purposely directing attention to particular features of the road environment. Their research was based on the early work of Johansson and Backlund (1970) who determined that traffic signs were more consistently remembered by subjects who had been cued to look for them than others who were not. The experimental design was one in which participants were assigned to four treatment levels: Free, memory, attention, and search. Those in the free condition were simply asked to watch the driving film. Those in the memory condition were informed that they would be asked questions at the conclusion of the film, but were told nothing about the content of the questions. The attention group was advised that it would be asked to identify all objects encountered in the visual display during the course of the film. Finally, the search group was told to explicitly report all road traffic control targets and any experimental discs that were placed along the roadside.

Half of the subjects in each condition performed the filmed observation task while performing a pursuit rotor task in the center of the display. The others simply watched the display without having to perform the dual task. Results showed that across groups, 25% of the fixations were located at the actual focus of expansion while 80% of the remaining fixations were centered within 6 degrees of the focus of expansion. Therefore, results suggest that if road signs are located beyond the 6° point in the display, they will probably not be perceived. Also, increasing task specificity (i.e., moving from the free condition to the search condition) resulted in more fixations to the left part of the display (the area where most signs were posted) with a corresponding decrease in fixations to the center of the display. Furthermore, the addition of the dual task paradigm resulted in two predominant effects on eye movements. First, eye fixations tended to move closer to the central region (where the pursuit rotor task was located). Second, the distance of peripheral fixation also moved closer to the focus of expansion.

Therefore, it can be concluded that in the dual task condition which requires increased attentional resources, there is insufficient spare resources to perform the tracking task without more fixation resources. This effect was hypothesized to arise from the need to make visual inquiry into the region of the tracking task. Also, pursuant to the second major finding in the dual task condition, the additional demand of the secondary task not only necessitates more fixations to the region of the task, but also reduces the extent to which the rest of the visual display is searched. Though not suggested by the researchers, these results could be accounted for in the context of attentional narrowing and/or distraction.

A similar study was conducted by Luoma (1988) to examine the types of roadway landmarks that are perceived and remembered better than others. As may be evident from the results of Hughes and Cole (1988) in the previous paragraph, and others (e.g., Drory & Shinar, 1982; Johansson & Backlund, 1970), drivers do not perceive nearly all of the traffic signs that they encounter, even in situations where they have been precued to look for the signs. In situations requiring increasing demand on the driving task, the perception of signs is even less than in "normal" driving conditions.

Luoma (1988) tested the idea that the more casual the perception or the larger the target signs, peripheral vision is used to a greater extent. However, an important function of peripheral vision is to identify targets of importance to the driving task and, if the situations warrants, direct focal vision to the sign. Another consideration is that even when focal vision is directed toward the sign, perception and further processing probably does not occur. To investigate these ideas, participants actually drove a 50 km route while outfitted in eye movement monitoring equipment. Along the route, they were asked to identify targets as they were passed and to report the essential content of each of the targets. If the participant only identified the target but was unable to report the content of the sign, it was not recorded as a correct perception.

Results indicated that correct perception only occurred, for the most part, when the target was fixated foveally. Also, whether the sign was perceived or not depended heavily upon the relevance of the sign to the driving task. For example, 100% of all speed limit targets were perceived foveally and were recalled while signs such as pedestrian crossings, roadside advertisements, and houses were perceived much less if at all. In fact,

no subjects recalled passing "pedestrian crossing" signs even though 25% of them fixated on it. Fixation duration was also recorded and these data suggested that in cases where the fixation time was extremely short, perception was not evident. Luoma (1988) interpreted this finding as suggestive that drivers did not even make an attempt to actually process the information. In general, results of previous studies were replicated in that overall, sign perception was rather poor. Furthermore, it appears that the processing devoted toward identifying the signs was dependent upon the relevance of the sign to the actual driving task and its informativeness.

Perhaps the most relevant study reported to date to examine the processing of visual stimuli in both central and peripheral fields was conducted by Miura (1990). The primary purpose was to assess changes in the useful field of view (UFOV) under situations of varying task demands and to determine the corresponding variation in the acquisition of visual information that accompanied these changes. The useful field of view can be superficially conceptualized as the information gathering area of the visual display. Mackworth (1976) has suggested that the UFOV will vary with changes in the situational characteristics or specific demands of the environment. Furthermore, Menz and Groner (1984) have suggested that the specific components that influence the UFOV are the width of processing and the depth of processing of visual information. Along these lines, Miura (1986) has shown that mean gaze duration becomes shorter in situations where demands increase, providing the impetus for the idea that the UFOV size shrinks under situations of high demand and the basis of this study.

The study was conducted under actual driving conditions in which the subject had to navigate along a roadway, in daylight conditions. Peripheral targets were presented at random at a distance of about 55 cm and varied in eccentricities depending on the point of fixation at the time of target presentation. The mean distance of eccentricity across all trials was approximately 13.6°. The dependent measures of interest were the RT to the peripheral stimulus and the distance between the target and the point of fixation at the moment of the participant's of response. The latter of the two has been shown to indicate the size of the UFOV. Both measures have been suggested to be the primary indices of peripheral visual performance (Miura, 1985). Five conditions were created varying the demands of the driving task accordingly. They consisted of: (1) sitting in a drivers seat in a stationary car, (2) driving on a low crowded road (LCR), (3) an expressway condition (EW), (4) a moderately crowded road condition (MCR), and (5) a highly crowded road condition (HCR). Driving demands were expected to increase correspondingly from the control (sitting in the stationary car) condition to the HCR condition.

Results showed that RT to the peripheral lights increased as the situational demands increased. Furthermore, response eccentricity became shorter, suggesting that the fixation must occur closer to the actual target location to acquire the necessary information. In general, this suggests that peripheral visual performance is impeded by an increase in situational demands. Specifically, it appears that the UFOV narrows at each fixation point, and the latency of each fixation lengthens. Miura (1990) also suggests that it is the temporal density of acquiring and processing information related the demands and not the speed of the driving itself that is responsible for the decrement in performance.

Furthermore, the detection of targets requires a greater number of eye movements in more demanding driving situations.

Miura (1990) offered two possible explanations for the decrease in peripheral performance as central demands increased. Based on the findings from an earlier work (Miura, 1987), he postulated that the depth of processing of an object in focus increases as the situational demands increase. Specifically, the latency period of the eye movements following fixation on a target lengthens as the demands increase. In more demanding situations, when a narrower UFOV exists, information pickup at the fixation point appears to be slower, causing a delay in the attentional switching capabilities of the driver. Other evidence (Miura, 1985) indicates that with lower demands, the fixation points shift to the inner area of the UFOV while during highly demanding situations, fixations shift toward the outer part of the UFOV. Thus, as a result of the deeper processing that occurs at each fixation point, participants attempt to acquire information more efficiently in the periphery while using a smaller UFOV. Another hypothesis is that as demands increase, they develop a stronger tendency to search for information in the periphery, a phenomenon referred to as "cognitive momentum", and a possible adaptation of the system to utilize attentional resources in the most efficient manner to deal with the increase in demands (Miura, 1986).

Though interesting and conceptually valuable, Miura's (1985, 1986, 1987, 1990) work fails to take into account what might be a primary influence on the decrement in peripheral performance and the apparent narrowing of the UFOV. Though not mentioned in any of his papers, a possible explanation for these findings can be attributed to the

increase in arousal and anxiety that accompanies tasks that increase in complexity and demands (Easterbrook, 1959). Although eye movements have been recorded in a variety of real world and simulated driving situations, researchers have not attempted to examine other, affective inputs to the system that may account for differences in performance. Furthermore, in Miura's (1990) study, as well as others, performance in the central driving task was not recorded.

Perhaps the driving quality of drivers varies based on the task demands, and changes differently than does performance in peripheral tasks. The resource allocation principle (e.g., Kahneman, 1973) would suggest that indeed this may be the case, but it has not been specifically investigated. More importantly, virtually no research has been directed toward assessing visual search and cue utilization in the context of high speed race car driving. Consequently, a large gap exists in the ability to generalize results obtained from studies of cognitive skills and closed sport skills to these high speed, dynamic, reactive settings.

Like normal driving, the sport of auto racing demands the coordination of an extensive repertoire of perceptual and motor skills. However, the performance difficulty of these skills is significantly compounded by the competitive nature of the sport. In addition to mastering typical driving skills, the shear speed of the car requires split-second decision-making and intense concentration on the most relevant cues. An ill-advised momentary attentional shift or distraction can be (and often is) catastrophic under these circumstances. Unfortunately, virtually no attempt has been made to empirically assess these factors in auto racing or in "traditional" sport settings.

Visual Attention and Sport

Though but few studies have been completed in the context of auto racing, other activities have provided excellent contexts in which to test the assumptions of the information processing model and its attentional limitations. For example, in fastball sports such as baseball and tennis, athletes often have as little as 200-300 ms in which to make decisions based on the intended direction and speed of the approaching ball (Hyllegard, 1991; Slater-Hammel & Stumpner, 1950, 1951), as well as to organize and execute the most appropriate movement to effectively coincide with the object in motion. Similarly, when driving a race car at 200+ mph, temporal constraints require extremely quick decision time and accuracy.

Visual Search in Sport

In recent years, the visual search activity of athletes has been examined as a means of discriminating performance expertise in sport tasks (e.g., Abernethy, 1990; Goulet, Bard, & Fleury, 1989; Helsen & Pauwels, 1990; Shank & Haywood, 1987; Williams, Davids, Burwitz, & Williams, 1994). Specifically, researchers have attempted to outline the mechanisms and patterns that differentiate experts and novices in their ability to perceive and use vital information in the sport environment. The majority of research performed in this area has been concerned with the relationship between visual search and selective attention, and with the influence of these processes on decision making strategies and eventual performance (Helsen & Pauwels, 1992, 1993).

Visual search applied to sport. Based on the models of visual attention proposed by Neisser (1967) and Yarbus (1967), researchers interested in the selective attention of

athletes of differing skill levels began to focus on the visual search patterns of athletes in applied externally-paced sport task situations in the mid-1970's (e.g., Bard & Fleury, 1976, 1981; Bard, Fleury, & Carriere, 1975; Ripoll, 1984, 1988). It was the contention in these studies that implications of the allocation of focal attention could be determined by examining the locations and durations of ocular fixation patterns. These patterns were assessed with eye-movement recording devices that measured ocular fixation through a corneal reflection technique (e.g., Bard & Fleury, 1981) while athletes viewed slides or videotape of particular sport situations.

Upon reviewing the sport-specific literature on selective attention and visual search, it is clear that differences exist between expert and novice performers (Abernethy, 1988). Visual search patterns of expert performers differ from novice performers in a wide variety of sports, including baseball (Bahill & LaRitz, 1984; Shank & Haywood, 1987), basketball (Vickers, 1996), fencing (Bard, Guezennec, & Papin, 1980), golf (Vickers, 1992), gymnastics judging (Bard, Fleury, Carriere, & Halle, 1980; Vickers, 1988), ice hockey (Bard & Fleury, 1981), soccer (Tyldesley, Bootsma, & Bomhoff, 1982; Williams et al., 1993, 1994), table tennis (Ripoll & Fleurance, 1985), tennis (Goulet, Bard, & Fleury, 1989; Singer, Cauraugh, Chen, Steinberg, & Frehlich, 1996), and volleyball (Ripoll, 1988; Sandu, 1982).

In the majority of these studies, experts required fewer fixations to achieve successful response outcomes, and exhibited lower search rates for sport-specific tasks. Also, experts made a greater number of fixations to the pertinent cues in the visual array than did novices, and had search rates that were (in the majority of studies) more

systematic and consistent than was the case with beginners (Abernethy, 1988). From these results, it would appear that the success of an expert's performance in anticipating, decision-making, and reacting is determined in part by where they look in the sport environment. That is, experts seem to have a more efficient visual search pattern in which they attend to only the most important aspects of the sport situation in which accurate and rapid perceptions and actions are required.

Visual search and gaze control. In addition to the visual search process, research on gaze control mechanisms of athletes has been conducted (Bahill & LaRitz, 1984; Vickers, 1992). Specifically, four types of basic eye movements have been defined. These include saccadic eye movements, used to rapidly scan from one fixation point to the next; vestibulo-ocular eye movements, used to maintain fixation to a target when the head is in motion; vergence eye movements, used to determine the distance between objects; and smooth-pursuit eye movements, used when tracking a moving object (Bahill & LaRitz, 1984).

Noting gaze control differences in a study of baseball batters, Bahill and LaRitz (1984) found that better hitters used faster smooth-pursuit eye movements, generated more anticipatory saccades, and had a greater ability to suppress the vestibulo-ocular reflex. Observing similar differences in an analysis of the putting stroke used by expert and novice golfers, Vickers (1992) reported that low handicap golfers (experts) possessed an economy of gaze allocation when compared to high handicap golfers (novices). Specifically, experts made more express saccades, had quicker saccades between gaze locations, and demonstrated greater fixation durations to the ball and target.

Taken together, visual search and gaze control research indicates that expert athletes have a highly systematic and selective process of focusing their attention, such that they know what to view, and when, in the visual field to glean the most informative cues. They make the most efficient and appropriate ocular movements to achieve this information pick-up. It can be assumed that experienced drivers in motor sports exhibit somewhat consistent eye movement patterns and tendencies which allow them to operate extremely fast race cars safely and effectively. As mentioned, very limited research has been directed to the examination of any psychological phenomena with race car drivers and none has been done to investigating driver's eye movements or other attentional parameters that are critical to high performance in the fastest sport in the world. The selective and divided attention demands of race car driving render it an ideal task and environment to investigate attentional mechanisms and the eye-movement parameters that underlie those mechanisms. Perhaps the first step that should be taken to better understand the attentional capabilities necessary for effective race car operation is to evaluate the visual search patterns of drivers as they navigate the race course. By evaluating these parameters, it may be possible to assess whether the "software" advantages that appear to predispose athletes in other sports to reach higher levels of achievement are valid antecedents to high performance auto racing.

Summary and Future Directions

As may be obvious from the literature summarized in this review, there are many questions remaining with regard to how performers are able to select and utilize the most critical cues and how anxiety, arousal, and attention interact to influence performance.

Consequently, the final section of the review will summarize the primary issues of interest and outline possible directions for future research in this area.

Most empirical research reported to date to examine the effects of arousal and/or anxiety on performance has been oriented in a very general fashion as exemplified by the dependent measures of both stress and performance that have been used. Very little is still known regarding the specific components of the stress response (either cognitive or somatic anxiety, arousal, or both) that influence specific performance variables such as attentional parameters, speed of information processing, and other cognitive factors. By examining these factors within the context of the relatively newly developed cusp catastrophe model and assessing specific aspects of performance, a greater understanding of these processes may be gathered and eventually lead to more accurate performance enhancement interventions geared toward these specific variables. For instance, if it was consistently determined that high levels of cognitive anxiety are actually beneficial to performance, typical anxiety regulation interventions (i.e., cognitive restructuring to minimize anxiety) would have to be re-evaluated.

One body of research that has been devoted to examining the emotional influence on cognitive factors is that dealing with the concept of attentional narrowing. Though intriguing, most studies to date have failed to indicate an accounting for the particular aspects of the stress response that lead to narrowing and further, have been unable to specify the specific mechanisms of the narrowing phenomenon. Consequently, research should be directed toward examining the particular perceptual (i.e., visual search characteristics) and processing (i.e., memory, response selection) aspects that lead to

peripheral narrowing. Also, in spite of the attractiveness of the narrowing idea, other theories may be able to account for the decrease in performance that is evident when stress levels are increased. One of the most attractive of these ideas is the idea of distractibility, the notion that as stress levels increase, the propensity of the performer to be distracted also increases. By devoting more attentional resources to distracting or irrelevant cues, less attentional resources are available for primary task performance. No research completed to date in the context of peripheral narrowing has been conducted in which actual distractors have been presented to participants while performing central and peripheral tasks.

Although the notions of attentional narrowing and hyperdistractibility appear to be contradictions, perhaps each contributes to performance variation in a complementary manner. Specifically, it appears as though attention may narrow during moderately high stress periods and that eventually, as stress levels continue to increase, the remaining attentional resources might be further consumed by an increased disposition to process interfering internal and/or external stimuli. Though empirical evidence does not exist to support this notion, anecdotal self-report from athletes and other performers warrants investigation into this area.

Finally, virtually no research, either basic or applied in nature, has been generated to examine the relationship of visual search patterns to peripheral narrowing under stressful conditions. However, it is logical that shifts in visual attention from central areas of a display to the periphery, and vice-versa, could be reflected, either directly or indirectly, in visual search fixation paths, duration, and locations. Furthermore, the use of

visual search may shed light on the question of distraction versus narrowing by indicating whether eye-movement patterns are altered in the context of high levels of stress. Therefore, it was my intention to attempt to delineate the contribution of distraction and/or narrowing within the context of visual search to help explain the performance changes that occur under stressful conditions. The specific objectives of my investigation will be described in the following and final section of the review.

Visual Search as an Indicator of Distraction and/or Peripheral Narrowing

As mentioned earlier, the visual search process consists of primarily two distinct stages. The first, the preattentive stage, involves the virtually unlimited capacity in which visual information from sensory receptors is held in a rapidly decaying sensory store (Neisser, 1967). Occurring without voluntary orientation of attention, this stage is involved primarily with crude feature analysis or detection. The second stage is a more focal or attention demanding stage during which the selected items in iconic store are analyzed further (Jonides, 1981, Remington & Pierce, 1984). In accordance with a early selection idea of attention (e.g., Treisman & Gelade, 1980), this is the phase when specific icons from the preattentive stage are passed from iconic store to the focal stage and processed for appropriate responses. Under conditions in which arousal and anxiety levels are optimal, cues deemed important to elicit appropriate responses will be utilized. Irrelevant cues may also be subjected to further processing, especially in underactivated situations where the mind is relatively free to wander. However, under stressful conditions, these irrelevant cues are funneled out of short term and working memory so that attention can be devoted to only the most relevant cues. With further increases in

stress, however, even relevant cues may not be permitted to enter higher levels of analysis and processing.

Visual search has been used extensively to draw cognitive inferences regarding what information is being extracted and processed during eye fixations, a concept Viviani (1990) has termed the "central dogma" of visual search research. Though it is presently impossible to empirically prove the central dogma, most researchers agree that eye fixations do at least reflect cognitive processing. Assuming the dogma to be even partially true, if an attenuation of cues in the periphery is evident, the need to pick up crucial cues in the periphery during particular situations would necessitate an increase in scan path variability and fixation rate in order to compensate for peripheral narrowing. Furthermore, if distracting visual cues were actually introduced into the test environment, visual search strategies may be altered, resulting in increased fixation and processing of distracting stimuli and a reduction of attentional resources available for central task performance.

Viviani (1990) suggested that the central dogma of visual search and cognitive inference would be valid if evidence for serial search is provided in particular tasks. According to Kahneman (1973), as arousal increases, task difficulty also increases. Under these circumstances, parallel (relatively automatic) processes tend to be modified by the organism, becoming more serial and attentive in nature (Duncan & Humphreys, 1989; Shiffrin & Schneider, 1977). In this case, the ability to relate eye fixations to cognitive information processing is more valid than when parallel processing is dominant.

In light of the lack of research which has been devoted to examining visual search mechanisms that may influence the sensitivity and processing of cues in peripheral

locations, investigations are warranted. As is evident by previous discussion, the driving environment provides an ecologically valid natural dual task paradigm in which to ideally investigate this phenomenon.

By assessing various components of the stress response including the independent and interactive effects of both cognitive anxiety and arousal, it was anticipated that a more complete understanding of the mechanisms responsible for the narrowing phenomenon would be gleaned. As may be obvious from the previous discussion of newer models of anxiety and arousal such as Hardy's catastrophe model (Hardy & Fazey, 1987), a re-examination of the attentional narrowing concept was justified. Along with contemporary understandings of the stress/performance relationship, this investigation was an attempt to clarify many of the loopholes that permeate previous literature on the subject. By introducing and evaluating the possible influence of distractors in the stressful environment, a more complete comprehension of the changes in performance at varying levels of stress was revealed.

CHAPTER 3

METHODS

In this experiment, the influence of anxiety on visual search patterns was examined in the context of a simulated high speed race car driving task. Data from this investigation provide a conceptual analysis of the anxiety/performance relationship and contribute to a greater understanding of the visual search and attentional mechanisms that underlie performance variation in stressful situations.

Participants

Female volunteers (N=48) selected from courses in the Department of Exercise and Sport Sciences at the University of Florida were randomly selected for this investigation and randomly assigned into six groups. Males were excluded from participation based on research findings that indicate they are less likely than females to report emotions, especially those of a distressful nature (Briscoe, 1985; Verbrugge, 1985). Furthermore, females have been shown to report higher levels of competitive state anxiety than males (e.g., Jones, & Cale, 1989).

The number of participants was determined by using Cohen's (1988) suggestions to maximize power and effect size. The values for entry into the sample size tables were as follows: a = .05 (level of significance), u = 10 [(k-1)(r-1)(p-1)], f = .40 (effect size),

and power = .80. No prior knowledge of the true purposes of the study nor the hypotheses being tested were provided. Also, only participants with 20/20 (reported) vision were tested. Participants with corrective eyeglasses were excluded due to the reduction in eye fixation recording capabilities that often occurs with wearing glasses.

Instruments and Tests

This section describes the specific tasks and physical equipment that were used in the study.

Central and Peripheral Tasks

Participants were tested in a simulated race car driving environment in which they were required to perform central and peripheral tasks. A dual task paradigm involving both central and peripheral stimuli has routinely been used in studies of attentional narrowing to delineate the attentional resource distribution between central and peripheral locations during task performance. It should be emphasized that participants were informed that both tasks were equally important in terms of the overall performance score so as not to confound any findings due to changes in probability expectations among participants (Hockey, 1970). The two tasks will be described in detail in the following sections.

Central task. The central task consisted of a simulated IndyCar driving task (IndyCar, 1996) which required each individual to navigate the race course (a simulation of the Michigan speedway) by controlling the steering, acceleration, and braking functions of the simulated Indy car. The Indy racing simulation was assembled from primarily three

components: (1) racing computer software, (2) analog steering wheel and foot pedals, and (3) video projection unit.

The racing software consisted of the Papyrus Design Group IndyCar Racing II CD (1996) and accompanying software. The program is a graphically refined, multi-option software package allowing external programming. The realism and graphics of the program have prompted such statements as "It's as close to the real thing as I've ever experienced" by IndyCar driver Stefan Johanssen (IndyCar, 1996). Optional programming includes but is not limited to track selection, track conditions, number of competitors, driving aids such as automatic shifting and braking functions, weather conditions, tire pressure and camber adjustments, and a variety of other choices. For the purpose of the study, the least complex of the track options (Michigan International Speedway) was chosen and all driving aids were selected to decrease task difficulty. By using driving aids, the only functions explicitly controlled by the driver were the steering, acceleration, and braking functions of the car. To aid in crash recovery, the automatic righting option was used to minimize recovery time in the case of an accident.

The driving functions of the simulation were controlled with an analog steering wheel and braking and acceleration pedals. All components worked in an analog fashion so as to increase the perception of reality while performing the task. In this way, if, for example, the participant was to quickly push the acceleration pedal to the floor, the result was loss of control of the car due to "roasting the tires" so to speak. Likewise, if the participant turned the steering wheel sharply, the severity of the turn was reflected in the abruptness of the visual scene change.

The realism of the simulation was enhanced further by the use of a Sharp Liquid Crystal Video Projection unit (Model #XG-H400U) that projected the display image generated from a Gateway 2000 P5-166 computer onto a large screen to make it appear life-size. In order to project the computer image, an Elite VGA to TV converter (Advanced Digital Systems, Model #FFN-100) converted the VGA image from the computer to a TV video signal that could be fed through the LCD projector.

Peripheral tasks. In order to examine more precisely the changes in performance that occur in highly stressful conditions, two types of peripheral stimuli were employed. The first peripheral stimulus was denoted as relevant to the driving task and in this way demanded attentional resources. The use of attention-demanding peripheral light stimuli has been used in other studies in which the attentional narrowing construct has been of interest. Specifically, the dual task paradigm was arranged such that participants were obliged to attend to the central task (driving the car) while having to concurrently detect and identify (through a button press response) the illumination of randomly intermittent red LEDs that were displayed in the periphery. The response button was mounted on the steering wheel to minimize interference with driving.

The red lights were illuminated, one at a time, on each side of the visual field at approximately 90° from the point of expansion (POE) in the driving display. This point was chosen based on pilot work which showed a dramatic loss in participants' color discrimination abilities at peripheral angles beyond 90°. Participants were required to identify the presence of the light as soon as possible while continuing to perform the central driving task as accurately and quickly as possible. Reaction time (RT) from the

time of illumination to the response was recorded for each trial through the use of a Lafayette Instrument Co. electronic timer (Model #54419-A). This type of cue was referred to as a "relevant" cue.

The second peripheral stimulus was used to assess whether performance changes in central and peripheral tasks were due to an actual narrowing of the attentional field, an increase in the distractibility of the participant, or both. The second peripheral stimulus was a green LED illuminated in the same peripheral position as the red LED from the previous description. By illuminating the green light in the same location as the red stimulus, the visual angle from the point of expansion (POE) to the peripheral location remained constant. Participants were required to perform the central driving task while ignoring the green peripheral stimulus. Any response made to the presence of the green stimulus was construed as a false alarm. This second type of stimulus was referred to as the "irrelevant" or "distracting" stimulus.

A total of four peripheral stimuli were presented at randomly chosen landmarks of the track for each lap (20 stimuli per trial block, 80 stimuli per test session). For example, on Lap 1, stimuli were presented in either the right or left peripheral field as the driver passed the end of pit row, as they entered the first turn, as the second set of advertisement signs came into view, and as they crossed the finish/starting line. On the following laps, random assignment of peripheral light color, peripheral locations, and track landmarks denoted subsequent stimulus characteristics. In this manner, any spatial and temporal biases that could confound attentional resource allocation processes were minimized.

As will become evident in the discussion of experimental conditions, two groups received only relevant stimuli while two others received a combination of relevant and distracting stimuli. In conditions where both relevant and distracting stimuli were presented, an equal number of each color were randomly presented in both right and left visual fields. Specifically, in some conditions, in addition to the red light that was illuminated in the task relevant condition, a green light may have been illuminated in the periphery at the same location (but not at the same time) as the task relevant cue. The task irrelevant stimuli was interspersed with task relevant stimuli but did not require a response and should have been ignored. After an illumination period of 3 sec, the lights were extinguished unless a response was made to the stimulus before the 3 sec period.

Measurement Recording Devices

The following instruments and equipment were used to record eye movement data, performance on the central and peripheral tasks, and levels of cognitive anxiety and arousal.

Eye Movement Apparatus

An Applied Science Laboratories (ASL; Waltham, MA) 4000 SU eye movement system was used to collect eye-movement information. The 4000 SU system is a video based monocular corneal reflection system that measures the point of gaze relative to video images recorded by a helmet mounted scene camera. The system has the capability to measure pupil position and corneal reflex which are used to compute visual gaze with respect to optics. Data from the left pupil and cornea were processed by a Gateway 2000 IBM compatible P5-133 computer and superimposed in the video image recorded by the

helmet mounted scene camera. In this respect, the exact point of gaze at all times could be evaluated frame by frame with respect to the visual display. System accuracy was ±1° visual angle with precision of 1° in both vertical and horizontal fields. Also, after calibration in relation to the head mounted scene camera, free movement of the head and eyes was permitted.

Visual search data. Visual search data was analyzed according to the procedures outlined by Williams, Davids, Burwitz, and Williams (1994). During the actual test sessions, recalibration of the eye monitoring equipment was performed following each trial block to insure the integrity of visual search data. The primary eye-movement measures of interest were exogenous saccades to peripheral lights, fixation location, and search rate.

Exogenous saccades. Saccadic activity refers to eye movements from one area of fixation to another. In this investigation, exogenous saccades were recorded following the presentation of each of the peripheral lights. Exogenous saccades refer to those saccades that are stimulus driven or initiated in a bottom-up fashion (i.e., the presentation of the stimulus causes a saccade to that location). Though it has been suggested that exogenous saccades are automatic and do not tap attentional resources (e.g., Pashler & O'Brien, 1993), the frequency of exogenous saccades was recorded as an index of the amount of time spent gazing to peripheral locations. In fact, because this measure was recorded on line, many of the saccades could possibly have been fixations. However, fixation information was also recorded off-line.

Fixation location. Fixation location refers to the areas in the display in which the eye fixates during completion of the tasks. Fixation location was coded for simplification

into four primary areas: (a) central locations (within 6° of the point of expansion), (b) 2 peripheral locations (i.e., the speedometer and rear view mirrors), and (c) irrelevant areas (outside the central and peripheral locations).

Search rate. Search rate was computed as a combination score representing the number of fixations and the duration of each fixation at particular locations as defined previously. Fixations were operationalized as a pause in search during which the eye remained stationary for a period equal to or in excess of four video frames (120 ms) (Williams, Davids, Burwitz, & Williams, 1994).

Central Task Performance

Central task performance measures of interest were the number of errors as well as the average lap speed. An error consisted of any deviation from the race course lane markers. Errors were further subdivided into two classifications: (a) major errors and (b) minor errors. Major errors were operationalized as driving errors which resulted in loss of control of the car causing the car to "spin out" and come to a complete stop before restarting. Minor errors were operationally defined as errors which did not result in total loss of control such as colliding with the wall or other drivers, driving into the grass, or driving below the white lane marker. Speed was recorded upon completion of each lap based on the average speed that was presented on the screen following each lap. Each of these measures was obtained by viewing the videotape recording obtained from the scene camera of the 4000 SU Eye Tracking System (ASL, 1995).

Peripheral Task Performance

Upon presentation of each peripheral stimulus, the participant was required to depress the response button (mounted on the steering wheel) to indicate they had recognized the stimulus. Response time was operationalized as the time between presentation of the stimulus and the button press. False alarms and misses (as described earlier) were also recorded.

Cognitive Anxiety Level

Cognitive anxiety was manipulated through the use of a contrived time-to-event paradigm and stress inducing instructional sets. The actual level of cognitive anxiety was measured before each test session with the short form of the CSAI-2 (Martens et al.,1990). The CSAI-2 (See Appendix A) has been shown to be a valid and reliable measure of cognitive anxiety, somatic anxiety, and self-confidence and has been used repeatedly to assess the independent contribution of these constructs to the stress response.

Physiological Arousal

Physiological arousal was assessed through measurement of heart rate. Resting heart rate (HR) baselines were obtained just prior to performance of the initial five trial blocks during the familiarization session. Session averages of heart rate were computed from data recorded after each trial block during the three sessions. A difference score was calculated for these sessions by subtracting the baseline rates from the data obtained during the test sessions.

Heart rate. Heart rate was recorded by a Polar (Polar Electro Inc., Model Accurex II) heart rate monitor (HRM) which was worn by all participants during performance of the tasks. The Polar Accurex II is a remote HRM consisting of a wrist worn data recording watch which collects a telemetrically projected signal from a transmitter worn just below the sternum. Average heart rate for each test session was reported.

Procedure

Upon entering the Motor Behavior Laboratory for testing, participants were informed that the general purpose of the experiment was to assess their eye movements as they drove a simulated race car under different task conditions. They were then asked to read and sign an Informed Consent form (See Appendix B), and questions regarding the study were answered. Following completion of the Informed Consent form, participants were outfitted in a Polar Accurex II HRM and a 1-min initial baseline heart rate was recorded as they complete the Competitive State Anxiety Inventory - 2 (CSAI-2: Martens et al., 1990). The measures of HR and cognitive anxiety served as baseline measures of anxiety and arousal for future comparisons. Following completion of the CSAI-2 and recording of heart rate information, last minute instructions were given (See Appendix C) and participants were seated at the driving apparatus.

Once seated at the apparatus, participants were asked to assume the position in which they would be most comfortable for the driving task. At this point, peripheral visual acuity was tested by illuminating the LEDs in the peripheral location and asking participants to respond by naming the color of the LED when the light was illuminated. The specific location of peripheral stimuli was determined individually due to variability

between participants with regard to peripheral visual acuity. Peripheral stimuli position coincided with the furthest distance from the POE in which color discrimination was still possible. This was operationalized as the point at which participants were able to achieve a 100% hit rate on five presented colors, and any movement beyond that point resulted in a lower hit rate.

After completing the peripheral stimulus identification check, participants were outfitted in an ASL 4000SU eye movement tracking system (Applied Science Laboratories, 1995) which was calibrated using a simple 9-point calibration reference grid. In this manner, their exact point of gaze corresponded to the fixation point as indicated by a cursor. The reference grid was presented through the video projector and generated by a computer graphics program (Microsoft Paint, 1995). The grid was the same size of the viewing screen so that the scope of fixation points corresponded to the size of the video image used during the simulation. After being calibrated, participants were ready to complete the experimental tasks. They completed three test sessions (including the familiarization session) according to specific experimental considerations based on the group to which they were randomly assigned. The first session occurred on the initial visit to the lab and then the second and third sessions took place two days later.

Experimental Groups

Participants were randomly assigned into six groups. Three of the six groups were exposed to multiple variations of anxiety and task conditions according to a contrived time-to-significant event paradigm and various instructional sets. As mentioned, the instructional sets used were similar to those administered by Hardy, Parfitt, & Pates

(1994) to manipulate levels of cognitive anxiety independent of somatic anxiety. These manipulations have been shown to be valid in both sport specific (Hardy et al., 1994) and other evaluative situations (e.g., Morris et al., 1981). Furthermore, the time-to-event paradigm has been shown to be a reliable means of investigating temporal changes in anxiety associated with impending competitions (Hardy, Parfitt, & Pates, 1994). Both the time-to-event paradigm and the instructional sets will be described in detail later.

The other three of the six groups were not exposed to the time-to-event anxiety manipulations. Rather, they merely completed three sessions in which they were told to perform the task as best that they could. These control groups were used to assure that changes in the other experimental conditions were due to anxiety manipulations and not mere practice effects or other confounding variables.

Control groups. As mentioned, three groups (the control groups) did not experience manipulations associated with the time-to-event paradigm or instructional sets geared towards increasing the level of anxiety. The first control group (*central control*) performed the central task without a peripheral task to perform congruently. The second control group (*relevant control*) performed both the central and peripheral tasks with the peripheral stimuli being the relevant (red) LED. The third control group (*distraction control*) performed both central and peripheral tasks, similar to the second group. However, the peripheral stimuli consisted of both task relevant (red LEDs) stimuli and task irrelevant (green LEDs) stimuli.

Anxiety groups. As mentioned, a contrived time-to-event paradigm and anxiety producing instructional sets were used to manipulate levels of anxiety for the other three

groups. Specifically, the time-to-event paradigm establishes a sequence of sessions which lead up to a competitive event in the final session. In the context of sport, this is similar to the athlete who has a preparation period leading up to the actual game or event of importance. Because volunteers and not actual athletes were used as participants in this study, the time-to-event paradigm required the manipulation of instructional sets which influenced the participants' perception that there actually was a significant competition at the end of the specified training period.

The fourth, fifth, and sixth experimental groups were each exposed to the instructional sets associated with the stages of the time-to-event paradigm. Specifically, the fourth group performed the central task without performing the peripheral task (the *central anxiety* condition) . The fifth group performed the central task but was also instructed to make a response to the relevant stimulus that was presented in the periphery at intermittent intervals (the *relevant anxiety* condition). The sixth group also performed the same central driving task, but was instructed to ignore the irrelevant stimuli and identify only the relevant ones that were presented in intermittent random intervals in the periphery (the *distraction anxiety* condition).

Those groups that experienced the anxiety manipulations completed three sessions denoted as a familiarization session, a practice session, and a competition session. The familiarization session was operationalized as the low anxiety condition, the practice session was the moderate anxiety condition, and the competition session was the high anxiety condition.

At the beginning of the familiarization session, participants were informed of the general format of the three sessions, the competition that would take place during the third session, and a $50.00 prize that would be given to the best performer. It was also emphasized that their overall performance score would be equally weighted by the ability to drive the car as fast and accident-free as possible while detecting as quickly and accurately as possible the presence of the peripheral lights. Furthermore, they were informed that the familiarization session should be used to gain an understanding of how to perform both the central and peripheral tasks and that their scores would not be evaluated in any way. However, they were also encouraged to do their best as this would help them prepare for the impending competition session (See Appendix D).

Following the familiarization session, each of the six groups completed two other experimental sessions two days after the familiarization session. The two sessions consisted of manipulations of anxiety according to the time-to-event paradigm for the *central anxiety*, *relevant anxiety*, and *distraction anxiety* conditions. Specifically, during the second session (the practice session), a moderate anxiety instructional set was used in which experimental groups were told that although the session was a practice session, their scores would be recorded and used for future comparison with other participants. Furthermore, it was stressed that they would have no more practice before the actual competition session (See Appendix E).

During the third session (the competition session), the high anxiety producing instructional set was used. Participants were told individually that their previous performances were good and that they were very close to winning the prize money. They

were also be shown a mock graphic depiction of their performance and how close they were to the top performer. Furthermore, at this time they were advised that the amount of extra credit they would receive was dependent on their performance in the competition session. Finally, they were notified that CNN and the Discovery channel are interested in this research and that if they performed well, they would be on TV as part of a science and technology special later in the Spring. A video camera was then assembled to mimic recording of the session. By providing an instructional set that highly stressed the importance of the competition, it was anticipated that the significance of the competition setting would become salient for the participant (See Appendix F). In this manner, the time-to-event paradigm was established to mimic actual competitive situations.

In total, all participants were required to complete 20 laps of the simulated 2 mi (3.4 km) course as quickly and as accurately as possible (i.e., minimize errors while maximizing lap speed) during each test session. A trial block condition was established in which there were 4 trial blocks for each test session with 5 trials (laps) per block. The approximate time required to complete each trial block depended on the number of collisions and average speed of the laps lasted approximately 5 min. See Table 3.1 for a representation of the research design.

Upon completion of the study, participants were asked to leave the testing area and debriefed as to the specific manipulations that were used and the true purpose of the study. They were then asked to complete a short post-experiment questionnaire as a manipulation check and to assess general feelings of driving efficacy (See Appendix G).

Table 3.1. Experimental Design

Experimental Design

Task Type	Familiarization Session 1	Practice Session 2	Competition Session 3
Central	low anxiety	low anxiety	low anxiety
Relevant	low anxiety	low anxiety	low anxiety
Distraction	low anxiety	low anxiety	low anxiety
Central	low anxiety	moderate anxiety	high anxiety
Relevant	low anxiety	moderate anxiety	high anxiety
Distraction	low anxiety	moderate anxiety	high anxiety

Finally, they were given the opportunity to ask any questions related to the study. All participants received full credit for participation regardless of performance on the task, and the best performer received a $50.00 award for her performance.

It should be emphasized that the manipulations provided by the instructional sets and the time-to-event paradigm were used to directly manipulate anxiety. Specifically, only cognitive anxiety and not arousal were directly manipulated in this experiment. However, in accordance with typical physiological responses to anxiety-producing stimuli, it was anticipated that the elevation in cognitive anxiety would indirectly produce increases in arousal level (Hardy & Fazey, 1987).

Data Analysis

Several analyses were used to examine data acquired on the dependent measures of interest in this investigation. Due to the interdependence and possible association of

each of the dependent measures with each other, independent analyses of variance (ANOVAs) rather than multivariate analyses of variance (MANOVAs) were the preferred procedures. The factors of interest were Groups (1-*central control*, 2- *central anxiety*, 3-*relevant control*, 4-*relevant anxiety*, 5-*distraction control*, 6-*distraction anxiety*), and Sessions (1-familiarization, 2-practice, 3-competition).

Anxiety and Arousal

Cognitive anxiety and arousal (HR and pupil diameter) data were evaluated with separate mixed model factorial ANOVAs. Cognitive anxiety scores during each session were analyzed with a 6 x 3 (Group x Session) mixed model factorial ANOVA with repeated measures on the second factor. For arousal, data was collected for each trial block and then collapsed across each session. The session means for HR and pupil diameter were then statistically analyzed with separate 6 x 3 (Group x Session) mixed model factorial ANOVAs with repeated measures on the last factor.

Central and Peripheral Tasks

As mentioned, the measures of central task proficiency were lap speed and driver error rate (major and minor errors). Means for each of these measures were calculated for the three test sessions. Lap speed and driving error information were each analyzed with separate 6 x 3 (Group x Session) mixed model factorial ANOVAs with repeated measures on the last factor.

Peripheral task performance was determined by analyzing both RT to the peripheral stimuli as well as the number of errors in peripheral light detection. These

measures were analyzed with separate 4 x 3 (Group x Session) mixed model factorial ANOVAs with repeated measures on the last factor.

Visual Search

The visual search measures of exogenous saccades, fixation location, and search rate were analyzed with separate 6 x 3 (Group x Session) mixed model factorial ANOVAs with repeated measures on the last factor. All visual search data used for analysis was taken from the middle (third) trial of each trial block completed during the three sessions.

Multiple Regression

Finally, separate multiple regression analyses were performed for each test session to examine the whether anxiety or arousal were predictive of changes in the various performance measures. In these analyses, anxiety and arousal were used as the predictor variables and were regressed against each of the performance factors. Finally, anxiety and arousal were regressed against each of the separate indices of visual search patterns to determine whether search strategy variations were predicted more accurately by physiological or cognitive mechanisms.

CHAPTER 4

RESULTS

For all statistical analyses performed, alpha was set at .05. In situations where sphericity was violated during repeated measures ANOVAs, the Greenhouse-Geisser adjusted p-value was used as the level of significance. Sheffé's post hoc analysis was applied to discriminate main effects, and simple effects tests were performed following any significant interactions. The chapter is arranged so that data concerning the anxiety manipulations and corresponding changes in arousal will be described first. Next, performance on the central driving task under the various experimental conditions will be presented. Visual search fixation data will then be summarized. Finally, results from multiple regression analyses will be described. Note that in all tables and figures, groups are denoted as such: *distraction-control* = D-C, *distraction-anxiety* = D-A, *relevant-control* = R-C, *relevant-anxiety* = R-A, *central-control* = C-C, *central-anxiety* = C-A.

Anxiety and Arousal

Cognitive anxiety was determined on the basis of data collected with the CSAI-2 (Martens et al., 1990). The index of arousal was heart rate (HR), which was collected with the Polar HRM. Data were analyzed with a separate 6 x 3 (Group x Session) ANOVA with repeated measures on the last factor.

Cognitive Anxiety

Analysis revealed a significant main effect for Session ($F_{(2,84)} = 11.95$, $p<.001$). More importantly, however, was the significant Group x Session interaction ($F_{(10, 84)} = 6.50$, $p<.001$). See Figure 4.1 for a graphic representation of the results. Simple effects analysis revealed that the *anxiety* groups significantly increased in cognitive anxiety levels during the competition session while the *control* groups remained stable across the three test sessions (See Table 4.1). There were no other significant effects found for anxiety.

Table 4.1

Cognitive Anxiety Levels for Each Group Across Sessions 1-3

	Session 1		Session 2		Session 3	
Group	M	SD	M	SD	M	SD
D-C	10.37	1.76	11	2.56	10.87	2.41
D-A	13.12	4.22	14.37	3.85	18.12	5.93
R-C	14.5	4.10	13.5	4.62	11.62	3.70
R-A	13	4.47	14	5.65	19.75	4.59
C-C	13.37	3.37	11.12	2.53	10.87	1.88
C-A	10.62	1.40	11.5	3.77	17.87	7.93

HR Change

Analysis of heart rate data indicated a significant main effect for Group ($F_{(5,42)} = 17.31$, $p<.001$) and Session ($F_{(2,84)} = 42.87$, $p<.001$). The relationships were described

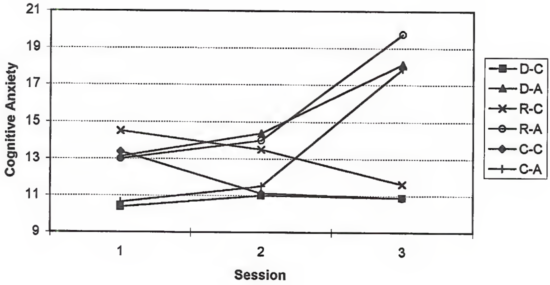

Figure 4.1. Changes in cognitive anxiety for each group across sessions 1-3.

more accurately, however, by the significant Group x Session interaction ($F_{(10,84)} = 29.04$, $p<.001$). Figure 4.2 provides a graphic depiction of the results. Simple effects analysis revealed that the three *anxiety* groups exhibited significant increases in HR in session 3 in comparison with the three *control* groups which remained stable or experienced decreases in HR (See Table 4.2). No other differences were found.

Table 4.2

Change from Baseline HR for Each Group Across Sessions 1-3

	Session 1		Session 2		Session 3	
Group	M	SD	M	SD	M	SD
D-C	-2.24	3.93	-8.37	5.01	-10.67	6.21
D-A	1.43	2.61	9.89	7.97	21.54	7.80
R-C	5.53	8.93	2	5.10	-1.53	5.24
R-A	3.39	3.00	10.56	5.68	23.24	7.14
C-C	1.81	5.08	2.68	5.76	0.43	6.17
C-A	2.06	3.91	6.18	5.33	19.15	6.25

Performance Data

Several factors were used as a basis for evaluating performance. Achievement on the central driving task was based on (1) lap speed, (2) the number of minor errors, and (3) the number of major errors. Performance on the peripheral light detection task was based on (1) response time to the peripheral stimuli, and (2) the number of misidentifications of peripheral lights. Performance differences were determined using

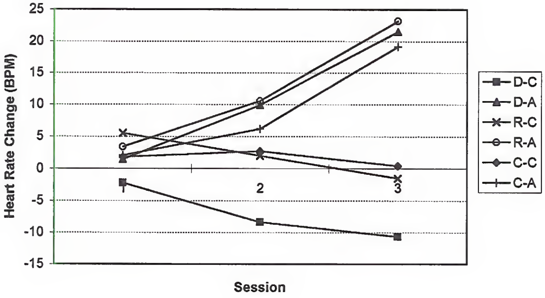

Figure 4.2. Change in HR from baseline rates for each group during sessions 1-3.

separate mixed design 6 x 3 (Group x Session) ANOVAs with repeated measures on the last factor.

Lap Speed

Lap speed was recorded after completion of each of the 60 laps and was averaged according to each 20-lap session. The analysis yielded a significant main effect for Session ($F_{(2,84)} = 70.83$, $p<.001$). A more meaningful finding, however, was the significant Group x Session interaction ($F_{(10,84)} = 3.63$, $p<.001$). Figure 4.3 graphically illustrates this result. Simple effects analyses revealed an interaction between two of the *anxiety* groups and the *control* groups. Specifically, the *distraction anxiety* group and the *central anxiety* group exhibited a significant increase in speed from Session 1 to Session 2 and then a significant decrease in speed from Session 2 to Session 3. Conversely, all *control* groups as well as the *relevant anxiety* group improved significantly from Session 1 to Session 3 (See Table 4.3).

Driving Errors

Driving errors were dichotomized based on the severity of the error as (1) major errors, and (2) minor errors. Each type of error was recorded and averaged for each of the three test sessions and analyzed separately.

Major errors. A significant main effect was found for Session ($F_{(2,84)} = 44.03$, $p<.001$). A more important finding, however, was the significant Group x Session interaction ($F_{(10,84)} = 2.00$, $p<.05$). See Figure 4.4 for a graphic representation of the interaction for major driving errors. Simple effects tests indicated that although all groups were able to significantly decrease the number of major errors from Session 1 to Session 2

and then stabilize from Session 2 to Session 3, the *distraction anxiety* group exhibited an increase in the number of major errors for Session 3 (See Table 4.4).

Table 4.3

Driving Performance (Lap Speed)

	Session 1		Session 2		Session 3	
Group	M	SD	M	SD	M	SD
D-C	161.87	16.90	170.58	16.17	184.95	9.95
D-A	170.54	8.74	185.52	12.86	176.50	17.51
R-C	161.88	9.43	181.50	8.57	185.56	7.20
R-A	160.83	15.30	182.04	15.62	185.92	10.16
C-C	166.53	17.91	184.51	9.94	190.40	6.73
C-A	175.46	11.94	190.45	7.91	182.26	4.85

Minor errors. Analysis of the minor errors yielded a significant main effect for Session ($F_{(2,84)} = 22.28$, $p < .001$). The Sheffé follow-up procedure indicated that the number of minor errors was significantly less in Sessions 2 and 3 ($M = 27.35$, $SD = 4.54$; $M = 25.38$, $SD = 7.86$, respectively) than in Session 1 ($M = 37.63$, $SD = 3.88$). No other significant main effects or interactions were found for minor errors.

Peripheral Task Performance

The two dependent measures used as indicators of peripheral stimulus identification proficiency were (1) response time (RT), and (2) number of mis-identifications (misses). Since the *central* groups did not perform the peripheral stimulus

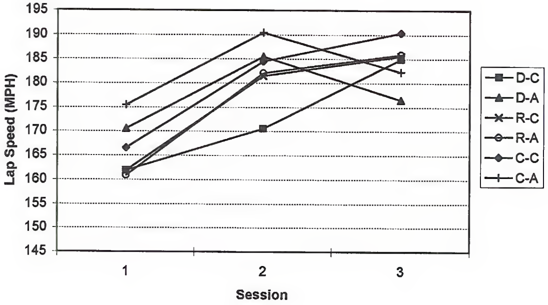

Figure 4.3. Lap speed for each group across sessions 1-3.

Table 4.4

Number of Major Driving Errors

	Session 1		Session 2		Session 3	
Group	M	SD	M	SD	M	SD
D-C	10.37	4.62	8.62	6.43	4	2.87
D-A	8.25	2.91	3.62	1.92	6.25	4.77
R-C	12.37	5.23	5.62	3.58	4.37	2.77
R-A	12.87	5.05	4.37	4.74	4.25	3.91
C-C	11.12	7.18	4.87	3.09	2.87	2.35
C-A	8.25	4.36	4	3.25	4.25	2.12

identification task, the only groups included in the analysis were those in the *relevant* and *distraction* conditions. Data for RT and number of misses were analyzed with separate mixed design 4 x 3 ANOVAs with repeated measures on the last factor.

Response time. The analysis of RT indicated a significant main effect for Group ($F_{(3,28)} = 6.29$, $p<.01$). More importantly, however, was the significant Group x Session interaction ($F_{(6,56)} = 6.76$, $p<.001$). A graphic depiction of the interaction can be seen in Figure 4.5. Simple effects tests suggested that no differences existed between groups in Session 1. However, the *distraction anxiety* group exhibited higher RTs than the *relevant control* group in Session 2. Furthermore, in Session 3, the *distraction anxiety* group responded slower to the peripheral stimulus than did the *distraction control* and

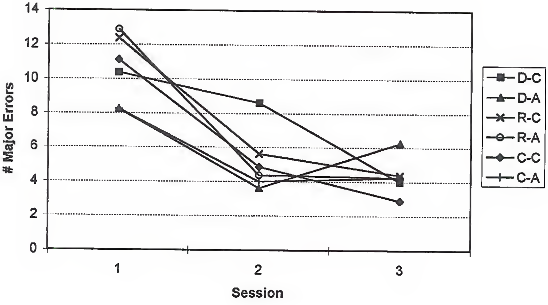

Figure 4.4. Number of major driving errors for each group across sessions 1-3.

relevant control groups. Similarly, in Session 3, the *relevant anxiety* group showed longer response times than did the *relevant control* group (See Table 4.5).

Table 4.5

Mean Response Time Across Sessions 1-3

	Session 1		Session 2		Session 3	
Group	M	SD	M	SD	M	SD
D-C	679.84	74.29	628.54	46.33	576.18	53.49
D-A	676.81	81.40	672.98	76.66	730.09	62.12
R-C	603.25	96.37	543.07	72.21	513.88	69.64
R-A	602.27	86.99	611.48	70.24	647.98	92.73

Number of misses. Results of the ANOVA on "miss" data revealed a significant main effect for Group ($F_{(3,28)} = 6.19$, $p<.01$). Of greater interest, however, was the significant Group x Session interaction ($F_{(6,56)} = 4.02$, $p<.01$). See Figure 4.6 for a graphic representation of the interaction for the number of misses. Simple effects analyses indicated no differences between groups in Session 1. However, in Session 2, the *relevant anxiety* group committed significantly more misses than did the *distraction control* and *relevant control* groups. In Session 3, the *distraction anxiety* and *relevant anxiety* groups exhibited significantly more misses than did the two *control* conditions. Furthermore, although the *relevant anxiety* group was significantly more error prone in Session 2, the *distraction anxiety* group committed significantly more misses during Session 3 (See Table 4.6).

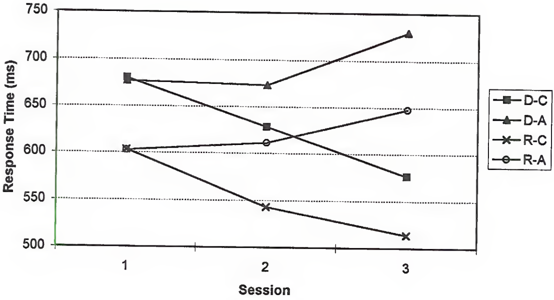

Figure 4.5. Mean response time across Sessions 1-3.

Table 4.6

Mean Number of Peripheral Light Misidentifications

	Session 1		Session 2		Session 3	
Group	M	SD	M	SD	M	SD
D-C	3	2.44	1	0.75	0.62	1.06
D-A	4	3.46	2	1.92	7.87	4.99
R-C	2.12	4.08	0.62	0.91	0.5	0.92
R-A	3.25	3.61	4.5	3.54	5.37	3.70

Visual Search Data

Measures of interest for the visual search data included (1) frequency of exogenous saccades to the peripheral stimuli, (2) fixation location, and (3) search rate. With the exception of the first dependent measure which was limited to the *relevant* and *distraction* conditions, other visual search data were analyzed with separate mixed design 6 x 3 ANOVAs with repeated measures on the last factor. Exogenous saccade information was analyzed with a 4 x 3 mixed design ANOVA with repeated measures on the last factor.

Exogenous Saccades

Analysis of exogenous saccades yielded significant main effects for Group ($F_{(3,28)}$ = 21.55, $p<.001$) and Session ($F_{(2,56)}$ = 18.77, $p<.001$). However, a more meaningful finding was the significant Group x Session interaction ($F_{(6,56)}$ = 23.73, $p<.001$). A graph illustrating these results can be seen in Figure 4.7. Simple effects tests indicated that in

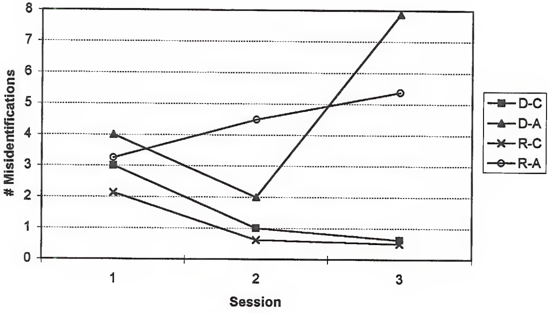

Figure 4.6. Mean number of peripheral light misidentifications.

Session 1, the *distraction* groups demonstrated significantly more saccades to the peripheral stimuli than did the *relevant* groups. In Sessions 2 and 3, although the *distraction control*, *relevant control*, and *relevant anxiety* groups exhibited similar saccadic activity, the *distraction anxiety* group made significantly more saccades to peripheral stimuli (See Table 4.7).

Table 4.7

Number of Saccades to Peripheral Stimuli

	Session 1		Session 2		Session 3	
Group	M	SD	M	SD	M	SD
D-C	9.5	5.29	6.87	6.72	6.62	7.57
D-A	10.5	6.78	24.37	9.60	42.5	20.50
R-C	3.25	3.10	2.37	1.99	0.87	1.12
R-A	2	1.06	2.87	3.48	4.62	2.82

Fixation Location

For the purpose of this study, fixation locations were coded into four areas: (1) the point of expansion (POE), (2) the speedometer, (3) rear view mirrors, and (4) off the projected viewing area. Of the locations of interest, the only differences between groups were found with respect to the number of fixations that occurred off the screen. These results are described next.

Analysis of fixation location data yielded a significant Group x Session interaction ($F_{(10,84)} = 1.97$, $p < .05$). A graphic representation of the results can be seen in Figure 4.8.

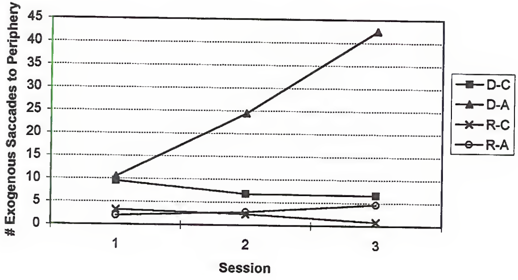

Figure 4.7. Number of saccades to peripheral stimuli across sessions 1-3.

Simple effects tests indicated that all groups exhibited similar fixation location tendencies during the first two sessions with the exception of the *relevant* and *distraction anxiety* groups which fixated significantly more often to the periphery. However, in Session 2 and 3 the *distraction control, relevant control,* and *relevant anxiety* groups demonstrated less fixations to peripheral locations than did the *distraction anxiety* group (See Table 4.8).

Table 4.8

Number of Fixations to Peripheral Locations Across Sessions 1-3

	Session 1		Session 2		Session 3	
Group	M	SD	M	SD	M	SD
D-C	4.67	.58	2.25	1.89	1	0
D-A	8.5	3.53	5.6	4.38	7.4	4.77
R-C	3.8	.95	3	.88	1.5	.71
R-A	9	8.99	2	0	2	0
C-C	1	0	1.5	1	2	0
C-A	5	4.36	1.25	.5	0	0

Search Rate

The final visual search data of interest in this investigation was the search rate exhibited by drivers or the overall duration of fixations at each location. No significant differences in search rate were found, however, with respect to the each of the four locations of interest.

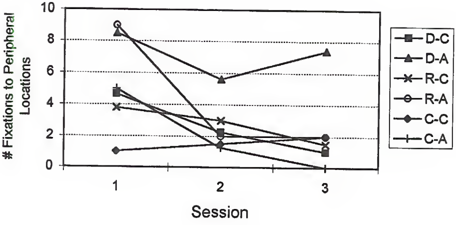

Figure 4.8. Number of fixations to peripheral locations across sessions 1-3.

Multiple Regression Analyses

Correlational research methods were also used to analyze the data and the Pearson Product-Moment intercorrelation coefficients for all variables can be seen in Appendix H. In addition to the use of ANOVA and simple correlations, stepwise multiple regression analyses were performed to determine which of the indicators of activation added to a linear function to predict changes in performance as measured by the indices of central and peripheral task proficiency. Also, it was of interest to determine whether visual search pattern alterations were predicted by variations in anxiety and arousal levels.

Activation and Performance

The predictor variables used in the multiple regression analysis were the levels of anxiety and arousal obtained for each session. The dependent variables included central task measures of lap speed, major errors, and minor errors, and peripheral task measures of response time and accuracy.

Central task. The predictor variables of anxiety and arousal were able to account for a significant amount of the variance in lap speed during Sessions 2 and 3. During Session 2, arousal accounted for more variability in lap speed than did anxiety. That is, as arousal level increased, so too did lap speed. However, during Session 3, anxiety level was the most influential predictor. In general, as anxiety levels increased, lap speed was detrimentally affected. Summary information for the multiple regression analyses can be seen in Table 4.9.

Table 4.9

Stepwise Multiple Regression Analysis Predicting Lap Speed with Activation Data Across Sessions 1 to 3

Variable	R^2	b	Beta	SEb	t	p
Session 2						
HR	.09	.45	.29	.22	2.07	.04
Session 3						
Anxiety	.11	-.59	-.33	.25	-2.38	.02

The total percentage of variability in lap speed explained by arousal was 8.5 % during Session 2. In Session 3, fluctuations in anxiety levels were able to account for approximately 11% of the variability in lap speed.

Peripheral task. Separate stepwise multiple regression analyses were also performed for peripheral task measures of response time and the number of misidentifications of peripheral stimuli. The analyses indicated that HR was able to account for a significant amount of variability in both measures during Session 3 and also during Session 2 for the number of misidentifications (See Tables 4.10 and 4.11).

The total amount of variability in peripheral task response time that was explained by heart rate change was 29% during the final session. With respect to the explained variability in misidentifications, heart rate change accounted for 16% in Session 2 and 40%

Table 4.10

Stepwise Multiple Regression Analysis Predicting Response Time with Activation Data Across Sessions 1 to 3

Variable	R^2	b	Beta	SEb	t	p
Session 3						
HR	.29	3.54	.54	1.01	3.50	.001

Table 4.11

Stepwise Multiple Regression Analysis Predicting Misidentifications of Peripheral Stimuli with Activation Data Across Sessions 1 to 3

Variable	R^2	b	Beta	SEb	t	p
Session 2						
HR	.16	.10	.40	.04	2.40	.02
Session 3						
HR	.40	.17	.63	.04	4.45	.001

in Session 3. In general, as HR increased, participants required more time to respond to peripheral lights and misidentified more stimuli.

Activation and Visual Search Patterns

Of the visual search patterns examined in the investigation, the number of saccades to peripheral locations was the only measure that was significantly predicted by activation changes and was significantly accounted for by fluctuation in anxiety levels (See Table 4.12).

Table 4.12

Stepwise Multiple Regression Analysis Predicting Exogenous Saccades with Activation Data Across Sessions 1 to 3

Variable	R^2	b	Beta	SEb	t	p
Session 3						
Anxiety	.14	1.3	.37	.59	2.20	.04

Anxiety variation accounted for 13.8% of the variability in the number of exogenous saccades to peripheral stimuli with more saccades occurring to peripheral areas as anxiety levels increased.

Manipulation Checks

In order to accurately study the measures of interest, it was critical that levels of arousal and anxiety were manipulated. As mentioned, the significant increases in both cognitive anxiety as well as heart rate provided verification for the potency of the time-to-event paradigm as well as the instructional sets used. To further substantiate the

effectiveness of these manipulations, a post-experiment questionnaire was distributed to participants at the completion of the study.

Items of relevance included questions regarding specific aspects of the instructional sets used. Participants were asked to rank on a Likert scale ranging from a score of 1 (not at all) to 7 (very much so) the degree to which they believed that (1) they would be on the Discovery channel, (2) they would receive $50.00 for being the best driver, (3) they were in second place after the practice session, and how much each of these factors affected them. They were also asked whether they believed that they would not receive full credit if they did not perform at a high level in the competition session.

Results of the post-experiment questionnaire confirmed that anxiety was manipulated in the expected direction. Participants rated their belief in anxiety manipulations from a low of 5.71 for the false feedback graph to a high of 6.04 for the $50.00 reward for the best driver. Also, the overall influence of the manipulations on anxiety levels produced an average score of 5.88. Taken collectively, the results of the manipulation check, CSAI-2 scores, and physiological arousal levels provide ample evidence that the manipulations were quite effective. Post experiment comments were also recorded and can be seen in Appendix G.

CHAPTER 5

DISCUSSION, SUMMARY, CONCLUSIONS, AND IMPLICATIONS FOR FURTHER RESEARCH

The attentional narrowing phenomenon relating activation levels to attentional processing has provided a theoretical framework for understanding the influence of stress on attention in a variety of basic and applied environments. Early investigations in this area led cognitive psychologists such as Bahrick, Fitts, and Rankin (1952) and Callaway and Thompson (1953) to theorize that at different levels of activation, the utilization of environmental cues changed in a predictable manner. This idea culminated in Easterbrook's (1959) influential article on the topic in which he explained attentional narrowing on the basis of several factors including the "intellectual competence" of the participant: i.e., knowing what cues to attend to at the appropriate times. His classic paper included an elaboration of the concept to specify the changes in attentional processing that occurred under increasing levels of emotionality and how this would affect performance on central and peripheral tasks in a dual task scenario. The necessity to select and process critical information in a timely manner is crucial to high achievement in sport. However, few researchers have attempted to examine the practical and theoretical implications of the attentional narrowing construct in the sport domain.

Though support for the concept of attentional narrowing has been provided in several investigations (e.g., Granger, 1953; Williams, Tonymon, & Andersen, 1990, 1991), the underlying mechanisms of the narrowing phenomenon have never been specified, but merely speculated. Findings have consistently indicated a decrement in performance on peripheral tasks with a corresponding facilitation of central task performance at moderate levels of activation when compared to lower levels. Similar support has been shown (though not quite as conclusively) that a decrease in performance of both central and peripheral tasks occurs at relatively high levels of anxiety/arousal (e.g., Bruner, Matter, & Papanek, 1955; Callaway & Dembo, 1958; Callaway & Thompson, 1953; Williams, Tonymon, & Andersen, 1990, 1991). Though the topic has been extensively researched, several gaps currently exist in the literature. For example, although numerous methods have been used to increase level of activation in participants (including anything from testing at variable depths of water to testing under extremely noisy conditions), few attempts have been made to identify the potentially unique influence of anxiety and arousal on performance, nor has it been possible to pinpoint the interactive effects of these factors (Hardy, 1996). Specifically, questions remain as to whether changes in performance are related primarily to physiological mechanisms (such as heart rate, skin resistance, and electroencephalographic activity) or to changes in cognitive indices of anxiety.

In addition to clarifying the activation/ performance relationship, another primary issue of interest was to provide evidence that many of the results of the narrowing phenomena could be accounted for in the context of distraction. Upon further examination of the literature which has been used to support the idea of a narrowing

phenomenon (e.g., Landers, 1980), it becomes quite evident that the same results can be described by a scenario in which participants become hyper-distracted at high levels of emotional energy. Accordingly, visual search data were incorporated in my investigation to shed light on the distraction/ narrowing question and to determine where performance changes may be rooted.

These issues provided the initial impetus of the investigation and will be discussed in this chapter. The first section deals with the observed changes in cognitive anxiety and arousal that occurred due to the use of the time-to-event paradigm and instructional sets. A description of the impact of the anxiety manipulations on performance of the central and peripheral tasks follows. Next, a discussion of the relationship of visual search patterns to performance and activation variations will be elaborated. In lieu of these considerations, an attempt will be made to describe the relationship between the attentional mechanisms that may have been influenced by anxiety and arousal and the effect of these attentional changes on performance. Finally, practical applications of this knowledge will be offered and the chapter will conclude with a discussion of future research directions pertaining to the topic of attention, anxiety, and performance.

Discussion

Changes in levels of cognitive anxiety and physiological arousal due to the use of the time-to-event paradigm and instructional sets are addressed next. Possible reasons for the trends in the data are also proposed in this section.

Cognitive Anxiety

It was hypothesized that the *anxiety* groups would experience changes in cognitive anxiety levels that would vary from low levels in the familiarization session to moderate

levels in the practice session, and eventually to high levels during the competition session. These changes were expected to occur in response to the time-to-event arrangement as well as the instructional sets used at each stage (Hardy, 1996). Conversely, it was expected that cognitive anxiety levels would remain relatively stable across the three sessions for *control* groups.

Scores on the cognitive anxiety subscale of the CSAI-2 (Martens et al., 1990) generally supported this prediction. Although anxiety levels increased slightly in the practice session for the *anxiety* groups, a dramatic increase in anxiety was evident during the competition session. Cognitive anxiety levels for the *control* groups remained stable across the three sessions and even decreased in two of the three groups.

Upon further examination of the data, it is evident that the manipulation of cognitive anxiety was successful. If this had not been the case, it would have been extremely difficult to draw any conclusions from the rest of the data and impossible to empirically evaluate the primary purposes of the study. Obviously, the manipulations used created feelings of anxiety that were reflected in both the self-report scores of the CSAI-2 as well as anecdotal comments regarding how the manipulations affected them (See Appendix G).

Aside from the anxiety increases experienced by those in *anxiety* groups, it is also important to note the decrease in anxiety levels of the *control* groups. Upon further consideration, this is an effect that should have been expected (Carver & Scheier, 1981). *control* group participants were unaware of any costs and benefits for performance on the task. They had no reason to fear any consequence of performing poorly (except perhaps embarrassment) and had no incentives to perform well. It would be expected that the first

session would be the most anxiety producing due to the lack of familiarity with the test conditions, discomfort felt in an unknown environment, and the like. One would presume, therefore, that as the experiment progressed, a level of comfort would be achieved and anxiety levels would drop. Furthermore, as participants were given extensive practice on the task, it appears that a comfort state was achieved which led to less wrecks and an increase in lap speed.

These findings are congruent with other studies of the multidimensional nature of anxiety in that the level of cognitive anxiety is expected to fluctuate based on the probability of success/failure and the consequences of success/failure (Jones & Hardy, 1990; Martens et al., 1990). In line with this notion, increases in cognitive anxiety would be expected for the *anxiety* groups due to the changes in instructional sets at each stage of the study. On the other hand, anxiety level in the *control* group would be expected to stay relatively the same or decrease based on the fact that they were given identical instructions at each stage.

Heart Rate

Substantial evidence has been compiled to suggest that as anxiety levels increase, one of the primary physiological indicators of arousal that accompanies this increase is accelerated heart rate. Though not a uniform or infallible measure of arousal due to individual response stereotypes (Lacey & Lacey, 1958), HR has been used extensively as a measure of arousal (e.g., Fazey & Hardy, 1988; Hardy, 1996; Hardy, Parfitt, & Pates, 1994; Parfitt, Hardy, & Pates, 1995) and, therefore, was of interest in this study. HR data were expected to reflect the general changes that occurred in anxiety across the three test sessions. More specifically, postulated was that those in the *anxiety* groups would

experience moderate increases in HR during Session 2 and then experience higher HR levels in Session 3. Meanwhile, it was hypothesized that those in the *control* conditions would experience stable or progressively decreasing heart rates from Session 1 to Session 3. In general, these expectations were supported.

Participants performing under the *anxiety* conditions experienced heightened levels of arousal in Session 2 and then even higher levels during Session 3. Conversely, *control* groups experienced very little change in heart rate across sessions and even demonstrated slight decreases in the measure. Though not the case for every participant, means for the groups suggest that HR variations reflected general changes in anxiety across sessions.

One very important implication of this finding is the fact that physiological indices of arousal could be measured and interpreted accordingly in the context of a natural response to anxiety-producing stimuli. In previous investigations of the cusp catastrophe model, for instance, arousal level of participants was artificially manipulated through strenuous exercise or other means (Hardy, Parfitt, & Pates, 1994). It could be contended, however, that this is not a valid means of varying arousal as it relates to the stress response. Simply increasing HR through exercise or otherwise does not necessarily provide an accurate indication of a physiological response to affective stimuli. By manipulating arousal in the manner used in this investigation (as a by-product of anxiety), it can be concluded that the increase in arousal reflected a physiological response to anxiety-producing stimuli. When arousal levels are manipulated through exercise or other unnatural means, it is impossible to attribute any change in arousal to cognitive or emotional mechanisms, or to understand how the person would respond in extremely anxiety-inducing circumstances without a cardiovascular workout beforehand.

The changes in arousal as well as anxiety allowed for valid comparisons of a variety of different emotional states and enabled the study of attentional mechanisms which were the major thrust of the study. The influence of these changes on performance will be discussed in the following section.

Dual Task Performance

As mentioned, considerable evidence exists which specifies the performance changes that occur in dual task situations under varying levels of activation (e.g., Landers, 1980). Several performance variables were of interest in this study. Due to the dual task nature of the experimental arrangement, specific hypotheses were directed toward each of variables based on their characteristics as measures of either central or peripheral tasks. Proficiency on the central driving task was based on measures of lap speed, the number of major errors, and the number of minor errors. Peripheral task dependent measures included response time (RT) to the peripheral lights and the number of misidentifications of peripheral stimuli. Each of these measures will be addressed in depth in the following section.

Central task performance. In line with the ideas of Easterbrook (1959) and others, it was postulated that the ability to drive the car (the central task) would follow the specified predictions of the cue utilization hypothesis. More directly, driving skill was expected to increase under moderate levels of anxiety and/or arousal (in comparison to baseline levels) and to decrease at high levels of activation.

Lap speed. One would expect to see an increase in overall lap speed for the *anxiety* groups during the practice session and then a decrease in lap speed during the

competition session. The *control* groups would be expected to exhibit a continuous increase in lap speed from Session 1 through Session 3.

Results confirmed the hypotheses for the *distraction anxiety* and *central anxiety* groups but not for the *relevant anxiety* group. *Control* groups also exhibited sequential increases in lap speed from Sessions 1 to 3 and, as expected, the *central control* group displayed the fastest competition session speed.

Interestingly, the *central anxiety* group demonstrated an extremely fast lap speed average during the second session. As may have been anticipated from Easterbrook's (1959) original predictions, performance on the central task at moderately high levels of anxiety would be expected to be higher than at low and high levels of activation. Evidently, the moderate level of anxiety and arousal experienced led to a facilitation in lap speed for the *central anxiety* group up to the level of the third session for the *central control* group.

As hypothesized, the *central anxiety* group and *distraction anxiety* group increased driving speed in the practice session but then exhibited a decrease in lap speed during the competition session. Though lap speed did not decrease to initial familiarization session levels, the drop was dramatic and in real terms would translate to an average decrease of 504 s during a 500 mile (810 km) race, a significant amount of time in auto racing. When placed in this context, the reduction in lap speed by those in the *anxiety* conditions would be seen as catastrophic by most racing standards.

<u>Error rate</u>. Error rate data were categorized based on their severity into two different classes: (1) major errors and (2) minor errors. Errors were dichotomized in order to more accurately identify the possible underlying causes for changes in lap speed.

Although it would have been less tedious to merely record any error and attempt to relate it to lap speed, such data may have been misleading. During pilot testing it was noticed that although a driver may commit five minor errors, they did not influence overall lap speed to the same degree of even one major error. It was expected, therefore, that major error rate would be highly related to lap speed and also more reflective of changes in affect and physiological arousal. Data acquired from error information will be discussed in the context of their relationship to lap speed and activation levels.

<u>Major errors</u>. Extrapolating from the original hypotheses directed toward central task performance, one would expect the *anxiety* conditions to decrease the number of major errors made on the driving task as they progress from the familiarization session to the practice session. Afterwards, an increase in the number of major errors would be expected during the competition session. In contrast, the number of major crashes should decrease sequentially from Session 1 to Session 3 for the *control* groups.

Data regarding the number of major errors were somewhat perplexing in light of the original predictions directed toward central task performance. Of the *anxiety* groups, the only one to perform as expected was the *distraction anxiety* group. Though decreasing the number of major errors from the familiarization session to the practice session, analysis of the competition session showed an increase in errors to levels slightly below the original familiarization session. In racing or even normal driving, one major error marks the end of a day, the destruction of a car, and possibly loss of life. In the context of this investigation, the number of major errors correlated highly with lap speed. Though other factors also led to lap speed increases or decreases, the ability to keep

control of the car was a major factor in predicting performance in this group, as indicated by the high correlations between the two variables.

Somewhat unexpectedly, the other *anxiety* groups exhibited similar trends to the *control* groups with respect to major errors. In general, these five groups showed decreases in major errors from Session 1 to Session 3. Taken with the data from lap speed, the results are somewhat confusing, especially with regard to the *central anxiety* group. As the number of major errors increased, lap speed should also increase. However, this was not the case. Although the rate of major errors remained relatively consistent for the *central anxiety* group, the average lap speed decreased by over 7 mph (12 kmph). Thus, it appears that other factors were responsible for the decrease in lap speed. In fact, much of the remaining variance in lap speed was accounted for in this group upon examination of the data acquired for minor errors.

<u>Minor errors</u>. As driving skill improved, it was expected that the number of minor errors would tend to decrease in a similar fashion to major errors from Session 1 to 3 for the *control* conditions. Furthermore, it was expected that those in the *anxiety* conditions would demonstrate a reduction in the number of minor incidents during the practice session, but not during the competition session.

The hypotheses held for *control* groups. As expected, minor error rates dropped from Session 1 to Session 3 and, as evidenced by moderate to high correlations, had a positive impact on the overall lap speed improvement made by these three groups. The same can be said of the *distraction anxiety* and *relevant anxiety* conditions.

An interesting finding, however, was that the *central anxiety* group seemed adversely affected by the number of minor errors, attaining a level in the competition

session that was similar to that exhibited during the familiarization session. Across groups, major errors had more impact on driving speed that minor errors. However, in this case, a large number of minor errors accounted for the observed decrease in lap speed during the competition session.

The different patterns of performance on the central task among the three *anxiety* groups can be explained more accurately by examining the aspect of performance that was primarily impacted across the three sessions. Although the maintenance of performance levels for the *relevant anxiety* group is difficult to explain, differences between the *distraction anxiety* and *central anxiety* groups may be better understood upon re-examination of error data.

Taking into consideration both error data as well as lap speed information, it becomes apparent where performance differences existed between the *central anxiety* condition and the *distraction anxiety* condition. Evidence obtained from minor error data suggests that drivers in the *central anxiety* group may have adopted a more cautious driving style during Session 3, favoring smaller errors and sacrificing driving speed for the assurance of less crashes. A strategic problem with driving too slow, however, is a tendency to make more minor errors due to the difficulty of keeping the car on the track. Because the racetrack turns are banked, they tend to force the car toward the infield at lower speeds, causing driving difficulty and over-correction problems. It appears that this may have been the case for the *central anxiety* condition.

In contrast, when examining the same performance variables for the *distraction anxiety* condition, trends are quite different. The relationship of major errors to lap speed in the third session was extremely high, accounting for approximately 80% of the variance

in lap speed during the third session. Perhaps drivers became more reckless, causing more accidents and a significant decrease in lap speed. In this case, the effect of anxiety on performance appears to be different from the *central anxiety* condition and may be a result of the absence of the dual task scenario in the *central anxiety* condition. An elaboration of this idea will be presented later.

Peripheral Task Performance

Two primary measures of peripheral task performance were examined in the study. They included (1) the number of misidentified lights and (2) the response time to identify relevant peripheral lights. Data related to both of these variables will be discussed in light of the hypotheses regarding the expected detriment in peripheral task performance as activation levels increased.

Response time. Several hypotheses were directed toward response time based on results obtained from previous tests of the attentional narrowing construct using dual task paradigms (e.g., Hockey, 1970; Williams et al., 1990; Yoo, 1996). First, it was suggested that the *anxiety* groups would respond more slowly to peripheral lights in the practice session than would the *control* groups. Furthermore, it was expected that this trend would continue in the competition session, but to a greater degree. Specifically, predicted was that the *anxiety* groups would respond slower to the peripheral lights in the competition session than they did in the practice session and that the *control* groups would respond faster to the peripheral lights in the competition session than in any previous sessions. Furthermore, it was hypothesized that the fastest response times would be exhibited by the *relevant control* group in the third session. Finally, it was suggested that

the *distraction* groups would perform proportionately worse than would the *relevant* groups (Eysenck, 1992).

Findings were generally supportive of the hypotheses. Specifically, *control* groups exhibited decreases in response time from the first to third sessions. *anxiety* groups showed opposite trends with RT increasing sequentially from Sessions 1 to 3. Also, as expected, the inclusion of irrelevant stimuli led to slower response times for the *distraction* groups as compared to the *control* groups. Across groups, the fastest response time was exhibited by the *relevant control* group, as expected. Furthermore, the slowest response time was demonstrated by the *distraction anxiety* group in the competition session. Not only was this a significant difference in comparison with other groups that were required to identify peripheral lights, but it was quite dramatic. The *relevant control* group displayed an advantage of more than 200 ms over the *distraction anxiety* group during the third session.

Misidentifications. Expectations for the number of misses were similar to those for response time. Specifically, it was expected that the *anxiety* groups would tend to miss more of the peripheral stimuli in the practice session and even more in the competition session than would the *control* groups. Also, it was hypothesized that the least number of misses would occur for the *relevant control* group during the third session and the most number of misses would occur for the *distraction anxiety* group during the same session. Results supported the hypotheses.

Overall, the *distraction* groups tended to be more inclined to misidentify a peripheral light than were the *relevant* groups. Also, as was expected, the *anxiety* groups misidentified more lights than did the *control* groups. Furthermore, the *distraction*

anxiety group missed more peripheral lights than did the *relevant anxiety* group under higher levels of anxiety. These results are to be expected based on the fact that the *relevant* groups merely identified the presence of any light while the *distraction* groups were required to decipher the nature of the peripheral stimulus as being relevant or a distractor.

Taken together with response time data, a clearer picture is painted of the influence of increased activation on the performance of peripheral tasks. The results of this investigation are not surprising in this respect. Virtually all published research dealing with attentional narrowing has clearly shown a detriment in performance of peripheral tasks as anxiety levels increase (e.g., Yoo, 1996). The unique contribution of the performance data summarized here, however, is the impact of distractors on peripheral task performance. Specifically, it appears that the impact of distractors becomes even more devastating at high activation levels, resulting in longer response times and more misidentifications.

Visual Search Data

Several indices of visual search tendencies were assessed during this investigation. Specifically, the dependent measures of interest included (1) exogenous saccades to peripheral stimuli, (2) fixation areas, and (3) search rate. The results of analyses performed on each of the visual search parameters will be discussed in the following section.

Exogenous Saccades

It was hypothesized that participants in the *anxiety* conditions would exhibit an increase in the number of exogenous saccades to peripheral stimuli. That is, they would

tend to make a shift in gaze from more central locations of the display to peripheral locations that corresponded with the onset of a peripheral stimulus. In accordance with the attentional narrowing theory, it was expected that this would be the case due to the lack of ability to notice and discriminate peripheral stimuli as the attentional field narrowed.

Participants in *anxiety* conditions were expected to systematically increase the number of saccades to peripheral areas from Session 1 to Session 3 due to the distracting and narrowing affect of anxiety. In contrast, it was hypothesized that those in the *control* conditions would tend to sequentially decrease the number of saccades to peripheral locations from Session 1 to 3 due to the higher degree of automaticity achieved in both tasks as participants were given the opportunity to practice, and the lack of interference from activation increases. Furthermore, it was expected that those in the *distraction anxiety* group would exhibit more saccadic activity at higher activation levels than would the *relevant anxiety* groups.

Results generally supported these hypotheses. The *control* groups were less likely to make saccades to the periphery as they progressed from Session 1 to 3. Also, as expected, the *anxiety* groups showed the opposite trend. As activation levels increased, so too did the number of saccades to peripheral locations. Furthermore, the *distraction anxiety* group tended to dramatically increase saccadic activity to peripheral locations, especially in the high anxiety condition.

<u>Fixation Location and Search Rate</u>

Hypotheses for fixation location and search rate paralleled those for exogenous saccades. Specifically, it was expected that with increasing levels of anxiety, more

fixations (duration of at least 120 ms) would occur to areas away from the POE (toward the periphery) in order to compensate for the narrowing of the attentional field and consequential lack of ability to differentiate distractors from relevant cues. Furthermore, it was expected that the duration of fixations to peripheral areas would increase.

Although support for fixation frequency to peripheral areas was supported, no statistically significant changes were observed for search rate. With respect to fixation location, the *distraction anxiety* condition exhibited more fixations to peripheral areas during the third session while the other three groups tended to demonstrate less fixations to peripheral locations during the same session.

These results can be taken as substantial support for the changes in performance that were predicted by attentional narrowing phenomenon, and also reinforce the idea that the narrowing phenomenon can be reflected in alterations of visual search patterns. Furthermore, changes in visual search patterns implicate perceptual mechanisms as a primary factor responsible for attentional narrowing. This notion will be addressed later.

Perhaps more importantly, this information involves visual distraction as an underlying mechanism for the performance changes that occur at high levels of anxiety and arousal. Although exogenous saccades may not be a direct indication of a shift in visual attention (e.g., Pashler & O'Brien, 1993), they do, however, indicate a shift in visual gaze away from the central task and toward irrelevant cues. Logically, by quadrupling the number of saccades to peripheral areas (as was the case for the *distraction-anxiety* group) less time was spent fixating on the central task. Taken together with the increase in the number of fixations to peripheral areas, it appears that higher levels of activation increase

the propensity to acquire information from cues outside of the useful field of view and thereby detrimentally influence central task performance.

In this respect, data are consistent with the notion that as demands increase, drivers develop a stronger tendency to search for information in the periphery, a phenomenon Miura (1986) referred to as “cognitive momentum”. Miura (1990) suggests that this is an adaptation of the attentional system to utilize resources in the most efficient manner to deal with the increase in demands. Though Miura (1990) did not mention attentional narrowing or distraction in his study, the visual search results from the present study support his ideas.

Another interesting finding is the fact that even though the number of exogenous saccades and fixations to peripheral areas increased, response time actually was longer in the last session for the *anxiety* conditions. The data indicate that participants may have adopted a different response style during the final test session. Specifically, it seems that drivers tended fixate more on peripheral lights in order to effectively discriminate the relevance of the light before responding to it. In earlier sessions, fewer shifts in gaze were made to the periphery, yet response accuracy was greater and so was response time. Both of these indices point not only to narrowing, but an increase in the tendency to be distracted by other cues when the driver was highly activated.

Summary of Findings

Due to the large number of dependent measures recorded in this study, a synopsis of the findings and an elaboration of their interactive effects will be provided in this section. Generally speaking, as arousal and anxiety levels increased, participants indeed

experienced attentional changes in both central and peripheral areas which led to corresponding performance changes.

Driving proficiency decrements were primarily noticed in measures of lap speed and the number of major errors experienced in the dual task situation. Individuals in the dual task scenario who experienced performance decrements at high levels of anxiety tended to show a decrease in lap speed as well as an increase in the number of major driving errors. However, in the single task environment, they appeared to become more cautious, as suggested by the increase in minor error rate at high levels of activation.

With respect to peripheral task performance, at higher levels of activation, drivers showed a decreased ability to respond to peripheral stimuli and were more inclined to misidentify the presence or the relevance of the stimuli. Furthermore, when distractors were included in the task environment, more time was required to identify the presence of these stimuli. This ability was further compounded by an increase in activation, leading to enhanced saliency of distracting stimuli and an higher propensity to respond to distractors.

Multiple regression analyses indicate another interesting point. Anxiety was more predictive, overall, of central task performance while arousal was more predictive of peripheral task performance. Furthermore, anxiety was more predictive of changes in visual search patterns (exogenous saccades). These findings will be described in comparison to those of Yoo (1996) in the following section of the chapter.

When combining the results from performance and visual search data, a more complete understanding of the interactions among variables is obtained. As anxiety levels increased, more saccades and fixations were made to peripheral locations. Though it is impossible to prove that these shifts in point of gaze absorbed attentional resources

(Viviani, 1990), they did divert the point of gaze away from the central task and toward peripheral areas. Correspondingly, it appears that this may have led to the performance decreases exhibited particularly by the *distraction anxiety* group.

Findings Which Contradict and Augment Previous Research

As is evident in the review of literature, a majority of studies conducted in the area of attentional narrowing demonstrate that performance on central and peripheral tasks varies in a predictable manner depending on the level of emotionality exhibited. However, the findings from this study are not completely congruent with the performance changes predicted by Easterbrook (1959). One would expect that in dual task situations, performance on peripheral tasks would decrease at moderate levels of activation and continue to be even more adversely influenced at higher levels. In fact, these propositions were fulfilled in the context of this investigation. However, central driving task performance was not totally consistent with the predictions of the attentional narrowing phenomenon. The lack of a performance decrease during the high anxiety session by those who were merely required to identify relevant cues is inconsistent with the predictions of the model.

A recent investigation by Yoo (1996), however, showed similar trends to the lack of a central task performance decrease exhibited by the *relevant anxiety* group. In Yoo's study, performance in the central task (a pursuit rotor) did not change at higher overall levels of cognitive anxiety. Results from other studies as well (e.g., Bacon, 1974; Wachtel, 1968) have been similar. That is, although peripheral task performance was affected in predicted directions, central task performance was not detrimentally influenced.

The present investigation may provide clues as to why the findings on central task performance have been somewhat equivocal. Evidence is provided here that distraction caused by irrelevant peripheral stimuli may have an effect on central driving proficiency above and beyond that described in the original framework of the attentional narrowing concept (Easterbrook, 1959). In order to embrace this argument, however, it is necessary to replicate the results of this study in others that involve the presence of distracting cues.

The principal goal of the Yoo (1996) study was to identify the aspect of the stress response which contributed most to changes in performance. To this end, cognitive anxiety accounted for most of the variance in the performance changes associated with the peripheral light identification task. This result is also inconsistent with the findings obtained in my investigation. Specifically, the primary predictor of peripheral task performance change (as measured by RT and misses) was physiological arousal (HR).

Perhaps more perplexing when relating Yoo's (1996) work to my study is the changes identified in central task performance. As mentioned, the most influential determinant of peripheral task performance in the familiarization and practice sessions was physiological arousal. However, during the competition session, cognitive anxiety was the primary predictor of lap speed. Though at odds with the findings of Yoo (1996), this result is consistent with predictions of the cusp catastrophe model which proposes cognitive anxiety as the splitting factor and the primary determinant of performance changes (Hardy, 1996).

Findings are even more intriguing with respect to visual fixation data which were collected as indications of attentional focus and gaze tendencies. In fact, neither arousal nor anxiety were significant predictors of the number of saccades made to peripheral

stimuli during the first two sessions. However, during the third session, cognitive anxiety was indeed a significant predictor of the number of saccades made to areas outside the UFOV. Thus, at higher levels of anxiety, more saccades were made to peripheral locations, and, correspondingly, lap speed markedly decreased. Evidently, the increase in the number of saccades away from the point of expansion impacted the ability to drive effectively as reflected in reduced lap speeds during the third session.

Theoretical Implications

One of the primary contributions of this study to the literature dealing with attentional narrowing is the inclusion of experimental conditions in which distractors are present along with relevant stimuli in peripheral locations. By including distractors in the testing environment, it was possible to investigate whether, in fact, attentional narrowing was the singular determinant of achievement changes at high anxiety levels or whether distraction played a significant role in these performance fluctuations. This and several other issues of theoretical importance will be revisited in this section of the chapter.

Numerous lines of evidence converge to indicate that indeed distraction was present at high levels of anxiety. First, performance on the peripheral light detection task was far worse under high anxiety levels for those in the *distraction anxiety* condition than for any other experimental condition. Not only was more time required to identify the presence of relevant stimuli, but also the number of misidentified stimuli increased.

Furthermore, performance on the central driving task was greatly hindered in this same group during the competition session while driving performance was not hindered in the other dual task conditions. Although this may not be a direct indication of an increase in distraction during the competition session, it appears as though the need to direct more

attention to peripheral stimuli absorbed resources that were necessary for central driving task proficiency.

Perhaps most convincing when attempting to plead a case for the role of distraction, however, was the increased number of fixations and saccades made to peripheral locations during the final, and highest, anxiety-producing situation. During this session, increased saccadic activity appeared to detract attention from the central task and led to more driving errors and slower lap speeds. Wegner (1994), Moran (1996), and others have presented anecdotal evidence to support the notion that as stress levels increase, the propensity to be distracted is enhanced. However, until the completion of my study, virtually no empirical evidence existed to support this notion. By including distracting stimuli in the experimental protocol, not only was the task made more ecologically valid, but answers were provided to verify speculation on this topic.

Another theoretical issue of interest was whether performance changes were due to variability in psychological affect (i.e., cognitive anxiety), an increase in arousal level, or some combination of both. This question was resolved in the context of my investigation yet also produced inconsistent data that raised more conjecture about the complex relationship of these factors to performance. The peripheral task appeared to be most negatively affected by relatively higher physiological arousal levels. In contrast, the primary predictor of changes in driving achievement was cognitive anxiety. Furthermore, the number of exogenous saccades made to peripheral stimuli was influenced mainly by cognitive anxiety.

As was alluded to earlier, the most troubling aspect of these findings is that they are almost opposite of the results reported by Yoo (1996), who found that peripheral task

performance was primarily impacted by cognitive anxiety levels and that arousal levels accounted for very little variability peripheral task identification ability. However, upon further scrutiny of Yoo's (1996) data, it becomes evident that over the three sessions, cognitive anxiety did not fluctuate. Furthermore, the values used for the median split between high and low anxiety groups was not reported and the variability accounted for by anxiety levels was quite small ($R^2 = .136$). Thus, these results should be interpreted with caution.

With respect to driving performance, cognitive anxiety was strongly associated with lap speed. Because the multidimensional nature of the anxiety response has not been previously examined in the dual task situation and therefore changes in the central task could not be attributed to specific predictor components, it is useful to compare these results to single task scenarios where changes have been noticed. Perhaps most relevant then, is Hardy's work with the cusp catastrophe model (e.g., Fazey & Hardy, 1988; Hardy, 1990; Hardy & Fazey, 1987; Hardy, Parfitt, & Pates, 1994; Parfitt, Hardy, & Pates, 1995) .

To reiterate the central postulates of the model, when cognitive anxiety is low, the model predicts that physiological arousal will influence performance in an inverted-U fashion. However, when physiological arousal is high, high levels of cognitive anxiety will result in lower levels of performance. Finally, when physiological arousal is low, higher cognitive anxiety will lead to increases in performance. Therefore, cognitive anxiety is projected to be the most influential determinant of performance changes at high levels of arousal.

In this study, high levels of arousal were exhibited during the competition session and cognitive anxiety accounted for a significant amount of variability during this session. Although these results do not provide concrete evidence for the specifications of the cusp catastrophe model, they point to cognitive anxiety as the splitting factor with regard to performance changes. Congruent with the predictions of the model, support is provided for the notion that cognitive anxiety level appears to be the most salient predictor of central task performance. Furthermore, as has been speculated by Hardy and others (e.g., Hardy, 1990; Hardy & Fazey, 1987; Hardy, Parfitt, & Pates, 1994), it appears as though the decrease in performance noticed for two of the three groups during the high anxiety stage was indeed quite catastrophic by both racing and normal driving standards.

Questions remain unanswered, however, with respect to the specific processes that are impacted due to elevated cognitive anxiety levels. Because changes in performance decrements were noticed not only in the dual task situation when distractors were present but also in the single task situation, it is not clear what mechanisms are being affected. As will be addressed later in this chapter, perhaps at high anxiety levels in the single task scenario, participants become more internally rather than externally distracted by worrisome thoughts and concerns (Moran, 1996).

Another goal of this investigation was to determine whether performance changes under higher levels of activation were due to the perceptual alterations in visual selective attention or other non-perceptual factors during the information processing of relevant and irrelevant stimuli. In other words, how can the information processing differences that occur under high levels of activation that lead to performance changes be explained? Proposed was that changes in visual search patterns would offer some clues as to where

these processing decrements occur, and would also provide some insight into the apparent lack of effective cue utilization at high activation levels.

Specifically, if visual search pattern activity remained relatively stable in spite of variability in proficiency levels of the central and peripheral tasks, it would be difficult to attribute these changes to perceptual mechanisms and would implicate later stages of processing (i.e., encoding, response selection). If, however, variability in performance changed in a manner that corresponded with visual search patterns, it could be surmised that different information was actually being gathered at the perceptual level (Abernethy, 1991). Thus, even if the information was being processed as efficiently as when one was not exposed to high levels of anxiety, in essence, irrelevant information was being processed.

In this study, differences indeed existed among groups with respect to visual search patterns. In fact, at high levels of anxiety and arousal, the number of fixations to the periphery and to distracting stimuli increased. As emphasized earlier, this provides sound evidence for the idea that perceptual mechanisms are changed which predispose performers to acquire and process irrelevant cues.

Relating this information to expert-novice studies dealing with visual search in sport-type situations, findings are relatively consistent with the typical search patterns of better performers across various sports. Overall, previous researchers have shown that the best performers tend to exhibit less fixations of longer durations to the most relevant areas of the display (e.g., Abernethy, 1988; Singer, Cauraugh, Chen, Steinberg, & Frehlich, 1996; Vickers, 1996). Though expertise was not a factor of interest in the present investigation, data indicate that the best driving performance was exhibited when

visual search patterns were less variable and more focused on the most informative driving cues. In contrast, the worst overall driving proficiency occurred when search patterns were more erratic and drifted to irrelevant cues.

The observed relationships among visual search, anxiety/arousal level, and performance also provide superficial support for the idea that visual search patterns are at least somewhat reflective of attentional focus [Viviani's (1990) notion of the "central dogma" of visual search research]. As elaborated in the review of literature, since Helmholtz first attempted to decouple attention from line of sight, researchers have been concerned with the ability to pinpoint the direction of attention from eye movement data (Abernethy, 1988; Viviani, 1990). With current measurement technology and paradigms it is impossible to resolve this issue. However, although not a specified goal of this investigation, it was hoped that the manipulations used would allow inferences to be made concerning the ability to infer shifts of attention from shifts in gaze. A recap of the primary criticisms directed toward visual search investigations follows.

Critics of the central dogma are quick to sequester support for the notion that attention can be allocated to areas other than the foveal fixation point (e.g., Buckholz, Martinelli, & Hewey, 1993; Davids, 1987; Remington, 1980; Remington & Pierce, 1984). Abernethy (1988) and Viviani (1990) have noted that merely "looking" at visual information does not necessarily equate with "seeing" (or comprehending) this information. Thus, a person may fixate upon pertinent cues in the visual array, but there is no guarantee that he or she is actually attending to or utilizing these cues.

According to Viviani (1990), three cognitive operations are inescapable when exploring the world to solve a problem. These include (1) activation of a set of a priori

beliefs about the possible states of the world, (2) breaking up the complex, holistic hypothesis that normally regulates interactions with the world into hierarchy of simpler alternatives, and (3) translating these alternatives into a sequence of locations in visual space that will likely disambiguate each alternative. These criteria appear to be valid in situations where eye movements are information driven, goal-directed behaviors, rather than simple stimulus driven percepts. If in fact, however, the specific search path is stimulus driven rather than goal driven (as was the case in this investigation), much of Viviani's arguments can be invalidated based on evidence that abrupt onsets of visual stimuli are virtually impossible to ignore and undeniably provide information which was not present in their abscence (e.g., Yantis, 1993).

Other criticisms levied by Viviani (1990) include the fact that because eye movements move in sequential order, representing strictly serial behavior, one must assume that the behavior viewed and corresponding thoughts unfold in sequential order. He suggests, therefore, that the central dogma would be valid of it was known that a given process unfolds sequentially. However, it is false whenever several concurrent processes can be suspected, unless a theory is developed that describes how eye movements reflect these processes.

He also contends that even if seriality can be assumed to be true, it is difficult to identify the conditions in which it is proper to assume that the sequence of visual operations actually conveys information. Support has been found for the notion that eye movements tend to cluster around areas of high informativeness (Antes, 1974: based on fixation clusters around corners) and this can be taken to support the central dogma. Other evidence that the line of sight coincides, at least somewhat, with the shift of visual

attention, is provided by investigations of the buffer capabilities of the brain and the lack of support for the notion that buffers exist (Potter, 1983).

In this examination, procedures (i.e., the introduction of anxiety-producing stimuli) were introduced to increase the ability to make inferences about attention from visual search patterns. As mentioned, Viviani (1990) proposed that the central dogma of visual search and cognitive inference would be more valid if evidence for serial search is provided in particular tasks. According to Kahneman (1973), as arousal increases, task difficulty also increases. Under these circumstances, parallel (relatively automatic) processes tend to be modified by the organism, becoming more serial and attentive in nature (Duncan & Humphreys, 1989; Shiffrin & Schneider, 1977). In this case (as was the case in this investigation), the ability to relate eye fixations to attention and information processing is more valid than when parallel processing is dominant. Furthermore, by including abruptly presented peripheral, the ability to infer a level of informativeness that did not exist previously is enhanced (Yantis, 1993).

Virtually all findings used to support the central dogma have been based on paradigms in which gaze shifts are initiated in a bottom-up, stimulus driven, exogenous manner (e.g., Just & Carpenter, 1976, 1980; Posner, 1980). In the exogenous context, Jacobs (1986) and others have provided evidence that each saccade brings the eye to a zone where new information can be gathered. However, once again, most evidence from scan path observations can only be used as support for the stimulus driven properties of eye movements.

I have suggested previously that the results of this investigation implicate the perceptual stages of processing due to the observed differences in fixation location and

exogenous saccades made to peripheral stimuli. More importantly, the shifting of gaze from central to peripheral locations was strongly associated with detrimental performance on the central driving task. Apparently, a shift in attentional resources away from the central location and to the periphery led to a lack of information acquisition from central locations. Admittedly, these findings do not support the notion that attention can be undeniably inferred from the line of sight in an endogenous manner. However, they do provide further substantiation for the role of gaze location on attentional focus in the processing of exogenous information.

Another area of theoretical interest was the effect of elevated activation levels on specific performance variables. In particular, by evaluating performance in terms of a variety of accuracy, speed, and reaction time measures, a more complete understanding of the separate elements of proficiency that are impaired or facilitated was ascertained. As Jones and Hardy (1990) have suggested, the lack off attention to these specific performance variables rendered it difficult, if not impossible, to prescribe interventions to enhance them.

Measures of central task proficiency were affected in a similar manner. As has been addressed frequently in this discussion of the data, lap speed was closely related to the number of major errors for all groups except the *central anxiety* group. However, after observing the minor error rate, it becomes evident that the effects of anxiety in single task scenarios seemed to be somewhat different than in dual task situations. Without having dichotomized error information into subcategories, these subtle differences would not have been noticed.

Similarly, misidentifications and response time varied in a comparable fashion. When combined with visual search information, however, it became clear that the changes in miss rate and RT occurred due to the increase in saccadic and fixation activity to peripheral areas. Once again, by including several behavioral measures as performance variables, it was possible to obtain a more complete picture of the influence of emotions on these factors.

Practical Implications

Practically speaking, this investigation provides several possible explanations for performance failures at high levels of anxiety and arousal both in the context of driving and other situations demanding continually quick and accurate responses. Though merely a simulation, the findings from this investigation give an indication of the manner in which excessive driving demands (such as heavy traffic, being "cut off", or near accidents) which increase the level of activation of drivers will negatively affect their attentional abilities. Furthermore, the impact of attentional abilities on the central task of driving the car (accelerating, braking, and steering) as well as the ability to detect and effectively process peripheral information were clarified.

Results are relatively unambiguous with regard to peripheral task performance. That is, performance on the peripheral tasks changed as expected from session to session as anxiety and arousal levels increased. From a practical point of view, one could surmise that under anxiety-producing circumstances, drivers (both race car drivers or otherwise) and athletes involved in sports requiring reactive capabilities may be more susceptible to missing important cues in the periphery and tend to be more distracted by irrelevant cues.

Similarly, in anxiety producing situations, drivers could be expected to respond less quickly to relevant cues and have a more difficult time ignoring distractors.

If this information is applied to actual driving situations, several possible inferences can be made. It can be expected that because drivers must consistently detect and respond to information in the periphery, their ability to do so will be inhibited under higher levels of activation. Consequently, important information that occurs outside the UFOV (such as warning signs, other cars, pedestrians, and the like) will not be noticed at all or will be responded to in a delayed fashion. The consequences of these performance changes vary on a continuum from inconsequential (if, in fact they have no bearing on driving or drivers' safety) to devastating (hitting a pedestrian or not avoiding a collision).

Practically speaking, the implications of the results of the central driving task for the everyday driver are somewhat different than for the race car driver. For the casual driver, perhaps the most relevant data here deal with the impact of higher activation levels on error rate. Although many drivers frequently drive under time constraints in which the faster they drive the better, the typical objective when riding to work, school, and extracurricular activities is not to see how fast the destination can be reached. Rather the usual objective is to arrive safely. Thus, error rate information is critical in this context.

Findings clearly indicate that a majority of errors occurred at highest individual activation levels. In this vein, evidence is provided that drivers may be more accident prone under stressful conditions, an observation that is supported by related research (e.g., Miura, 1990). An awareness of this fact by the everyday driver could prove to be critical in mediating the emotional response to typical anxiety producing roadway occurrences such as time constraints, poor driving conditions, inconsiderate drivers, near accidents,

and the presence of law enforcement officials. Based on the results of my research and other studies, recommendations include increasing the awareness of attentional problems that occur under stressful driving conditions, and encouraging the use of arousal regulation strategies to mediate these effects.

In the context of race car driving, not only is the safety of the driver critical, but the maintenance of high speed becomes of paramount importance. In order to drive efficiently and safely while monitoring other factors such as engine temperature, tire pressure, fuel levels, and other competitors, the driver must possess a high degree of attentional flexibility. Furthermore, the ability to extend this high level of concentration throughout the duration of a 4-hour race necessitates the ability the keep attention focused in the most relevant, information rich areas of the environment at all times. Any possible maladaptive influence such as that produced by emotional concerns must be minimized. Creating an awareness of the impact of anxiety on attentional processes is the first step in helping drivers to regulate thoughts and emotions more effectively, leading to higher performance.

Summary

The purpose of this investigation was to examine the influence of distraction on the attentional narrowing construct in the context of a dual task driving simulation under varying levels of anxiety. Forty-eight women were randomly assigned to one of six experimental conditions: *distraction control*, *distraction anxiety*, *relevant control*, *relevant anxiety*, *central control*, and *central anxiety*. Those assigned to *central* conditions only performed a driving task while the other four groups were required to identify peripheral lights in addition to driving. Those in *anxiety* conditions were exposed

to increasing levels of anxiety as manipulated by instructional sets. All participants completed three sessions consisting of 20 trials each during which measures of cognitive anxiety, arousal, visual search patterns, and performance were recorded.

Data indicated that as individuals in dual task conditions reached higher levels of anxiety, their ability to identify peripheral lights became slower and less accurate. Furthermore, driving ability for those in the *distraction* and *central* groups was impaired at high levels of anxiety. The decrease in driving proficiency for the *distraction anxiety* group was highly associated with a shift in visual search patterns toward peripheral locations. With respect to the *central anxiety* condition, driving proficiency was heavily influenced by an increased tendency to make minor errors which could be attributed to a more cautious driving style when highly activated. Overall, performance in both central and peripheral tasks was worse for the *distraction anxiety* group during the period of highest anxiety. Furthermore, visual search patterns tended to increasingly drift to peripheral areas during the high anxiety session for this group.

Results suggest that drivers who are highly anxious and aroused experience an altered ability to process peripheral information at the perceptual level, leading to a decrease in attentional resources available for the processing of central information. In addition, it appears that this effect is amplified when distractors as well as relevant cues are present in peripheral areas. Implicated in the study is the role of visual search patterns and distractors in the dual task context. Suggestions are made to revise the current notion of attentional narrowing to include the role of distraction as a contributor to performance variability.

Conclusions

Based on the findings of the study, the following conclusions are made:

1. With increases in anxiety and arousal to high levels, performance in peripheral tasks tends to be detrimentally affected due to a narrowing of the attentional field. When distractors are added to the peripheral task environment, this effect is compounded and appears to alter visual search patterns. The alteration in visual search patterns in which more fixations are directed toward peripheral areas of the display is associated with a debilitative effect on central task performance.

2. The central tenants of the attentional narrowing concept should be revised to incorporate the role of distraction in performance changes. The results of this study do not contradict the attentional narrowing phenomenon, but add a dimension to it that provides further explanation for the influence of attentional changes on task proficiency.

3. From a practical point of view, driving instruction personnel, trainers, and sport psychologists must be aware of the possible impact of anxiety and arousal on attentional abilities. A need exists to create awareness of the reasons for the detrimental effects of anxiety and arousal on performance among pilots, casual drivers, auto racers, athletes, and a multitude of other occupations and trades. By combining this awareness with cognitive, self-regulatory strategies such as those used by the most effective and safest participants in various sports and activities, individuals will develop the ability to be better prepared to deal with emotional circumstances when they arise.

Issues for Future Consideration

Several issues remain unresolved in spite of this comprehensive investigation, and others have arisen during the course of collecting these data that will provide fruitful areas of research in the future.

1. This study was the first in which the influence of distractors were investigated in the context of an attentional narrowing dual task paradigm, and one of the first in which the impact of activation changes on visual search patterns were examined. Because it is a seminal investigation, replication of these results would add to the predictive value of the data as well as an understanding of whether or not the findings are generalizable to other situations and populations. With this in mind, it would be of interest to examine this paradigm with athletes in other high speed reactive sports. Furthermore, perhaps future investigations could be directed toward assessment of attentional cue utilization and distraction in self-paced, closed sports. Finally, due to the decline in perceptual skills and RT in elderly drivers, combined with the increasing fear of driving that often occurs with age, studies could be undertaken to understand more thoroughly whether safety is being compromised in older populations with regard to the measures recorded in my investigation. These findings could also be used to develop comprehensive driving tests which are based not only on static but also dynamic visual acuity.

2. One possible limitation in the present study was the use of young, relatively inexperienced female participants. It would be interesting to see the effect of performer expertise on the variables of interest in this investigation. This could be accomplished in two different ways. First, it would be highly desirable to have access to some of the best

drivers in the world and to examine whether their search patterns and performance changes are similar to those observed for lower skill-level drivers. Alternatively, participants (either aspiring professional drivers or "normal" drivers) could be trained to certain criterion levels and then exposed to similar instructional sets and anxiety manipulations that were used in this investigation to examine attentional changes across varying degrees of expertise.

As mentioned previously, one of the practical implications of this research is the establishment of attentional training protocols that are based on the profiles exhibited by the safest and most efficient performers. The expert-novice paradigm has proved useful in the study of visual search differences in other sport domains (e.g., Abernethy, 1990; Goulet, Bard, & Fleury, 1989; Helsen & Pauwels, 1990; Shank & Haywood, 1987; Williams, Davids, Burwitz, & Williams, 1994). The results of my investigation provide an indication of the visual search patterns associated with varying proficiency levels. Correspondingly, one would expect that expert visual search patterns would be consistent with those observed for individuals who performed at a high level in my investigation. However, without explicitly testing experts, it remains unknown whether these patterns are similar to those exhibited by the best performers.

3. A disappointing finding in this investigation was the lack of clarification provided with respect to the relationship between various components of the stress response and their influence on both central and peripheral tasks. Because both arousal and anxiety levels varied similarly in the *anxiety* groups, it was difficult to observe the effect of a change in anxiety independent of a change in heart rate - they occurred relatively simultaneously. If, in fact, anxiety and heart rate scores varied in a dissimilar

fashion, a more valid identification of which aspect of the stress response contributed most to changes in performance of both tasks would have been possible. Perhaps future researcher attempts should be made to provide instructions that are geared toward manipulating one aspect of the stress response independently of the other as Hardy and his colleagues have done in past studies of the cusp catastrophe model (Hardy, 1996).

Furthermore, although cognitive anxiety levels increased significantly in this investigation from Session 1 to Session 3, they did not approach maximum scores, even in the high anxiety conditions. These findings are relatively consistent with studies in which anxiety has been manipulated (e.g., Parfitt et al., 1995), but fall well short of others in which the cusp catastrophe model has been of interest (e.g., Hardy et al., 1994). Accordingly, it would be of interest to examine whether even higher levels of cognitive anxiety (and arousal) influence performance in a similar (and possibly more dramatic) fashion to that demonstrated in my study.

4. Though the results of the study were relatively clear with regard to the impact of arousal and anxiety on the central task, it is difficult to pinpoint the underlying cause of this relationship when there was no performance decrement exhibited by the *relevant anxiety* condition at high levels of activation. As mentioned, central task performance changes have been rather equivocal in the study of attentional narrowing. Perhaps there are other, uncontrolled variables which render the affect of anxiety as positive or negative, but have not been elaborated thus far.

It has been proposed that one of the primary influences or mediators of the anxiety-performance relationship could be self-confidence (Martens et al., 1990). The underlying assumption to this argument is the idea that although anxiety may increase, if

the performer maintains a high level of self-confidence, the rise in anxiety levels will be facilitative to performance. In the context of my investigation, this may, indeed have been the mediating factor that led to performance facilitation for the *relevant anxiety* group even as they achieved high levels of anxiety. One would expect that if, in fact, self-confidence does play a major role in the effects of anxiety on performance, the detrimental consequences of attentional narrowing and distraction would be minimized.

It would also be valuable to examine more closely why there was a change in the single task only situation. Proposed was that this may be due to an increase in internal distraction as opposed to external distraction (Moran, 1996). The paradigm used in this investigation only permitted empirical testing of external distraction. However, it is logical to suggest that because there are fewer variables to consume attentional resources in a single versus a dual task scenario, those resources may be directed more internally to the anxious feelings themselves.

Perhaps the degree of internal distraction could be reflected by the level of somatic anxiety. By definition, somatic anxiety is associated with the perception of arousal (Martens et al., 1990). If somatic anxiety levels remain high, this could be an indication that arousal has become more salient to the participant, and that attentional resources have been diverted to perceiving these physiological signs. In this respect, attentional resources would be reduced for the processing of task-relevant cues and performance would be expected to decrease.

5. Another possible improvement to the present study would be a comparison of the simulation used here to the actual auto racing environment. Although simulations tend to provide an environment that is similar to the actual one, what is gained in terms of the

ability to control the testing situation may be compromised by a loss of pertinent data. One of the intentions of this study was to test the constructs of interest in an ecologically valid environment. This was accomplished to a large extent by the use of a simulation. However, other factors such as the g-forces exerted on the drivers, the lack of communication between crew chief and driver, and the real competitive and life-threatening stimuli that are part of the actual racing environment were not included in this investigation.

Perhaps these other factors play a significant role in determining driving performance beyond that which was evidenced in my study. By including other factors that require attentional focus and flexibility, a more complete understanding of the attentional narrowing phenomenon and practical ramifications of this phenomenon to the actual racing environment may be obtained. Though instrumentation would be virtually impossible at the present time, this may be a possibility in the future with the development of lightweight, highly compact, and portable eye movement systems.

6. Another area of concern is the possibility that by notifying participants that a distractor may be present, attention may have been more inclined to be drawn to irrelevant cues. Wegner (1994, 1997) has suggested that people tend to exhibit what he terms "ironic mental processes" when confronted with a variety of information. The central notion to Wegner's theory is that when trying to avoid thinking about a particular thought or object, or ignoring it, attention is inadvertently drawn to the exact thing one is trying to ignore.

With regard to the practical applications of this research, I have advocated an awareness strategy as one that would be most beneficial to performers. That is,

individuals should become aware of the attentional changes that occur when highly emotional as a first step in overcoming the negative consequences of these changes. In light of Wegner's ideas however, perhaps more mainstream awareness interventions should be tempered with non-awareness strategies and "paradoxical interventions" that free the mind from distraction. These ideas have far-reaching implications to many traditional sport psychology interventions used presently. Investigation of this phenomenon in the sport domain could provide valuable insight to the role of (especially) internal distraction not only in sport but in other domains as well.

7. Finally, though differences were found among several visual search parameters, others could have been included in the analysis which may have provided valuable insights. For example, measures such as the total number of fixations, how many different areas were fixated, what part of the UFOV was fixated, and the like, could provide clues as to where perceptual differences exist as performance changes. Including these variables in future studies could be of value in continuing to unravel some of the mysteries of the attentional narrowing phenomenon and the impact of distraction on performance.

Final Comment

In conclusion, this study addressed a critical issue in the broad realm of health and human performance: The necessity of attending to and processing relevant information in an efficient manner. Without this capacity, human performance is greatly compromised in a variety of different environments. Furthermore, the ability to excel, especially in the sport context, is highly dependent on the continual refinement and appropriate application of these attentional skills. Previous evidence has suggested that when placed in stressful environments, attentional ability of participants is negatively modified by a narrowing of

the attentional field. The present results indicate that although this may be the case, the influence of anxiety on attention is also determined by distraction. On the basis of this evidence, I conclude that individuals in situations which require the continuous monitoring of both central and peripheral cues should be aware of the influence of anxiety on attention, and take appropriate measures to reduce the potentially devastating consequences of ignoring these attentional alterations.

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APPENDIX A

COMPETITIVE STATE ANXIETY INVENTORY - 2 (CSAI-2)

Racing Self-Evaluation Questionnaire

Name: ________________________ Sex: M F Date: ____________

Directions: A number of statements which athletes have used to describe their feelings before competition are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate *how you feel right now - at this moment.* There are no right or wrong answers. Do not spend too much time on any one statement, but choose the answer that describes your feelings *right now.*

	Not At All	Somewhat	Moderately So	Very much So
1. I am concerned about this competition	1	2	3	4
2. I feel nervous.	1	2	3	4
3. I feel at ease.	1	2	3	4
4. I have self-doubts.	1	2	3	4
5. I feel jittery.	1	2	3	4
6. I feel comfortable.	1	2	3	4
7. I am concerned that I may not do as well in this competition as I could. .	1	2	3	4
8. My body feels tense.	1	2	3	4
9. I feel self-confident.	1	2	3	4
10. I am concerned about losing.	1	2	3	4
11. I feel tense in my stomach.	1	2	3	4
12. I feel secure.	1	2	3	4
13. I am concerned about choking under pressure.	1	2	3	4
14. My body feels relaxed.	1	2	3	4
15. I'm confident that I can meet the challenge.	1	2	3	4
16. I'm concerned about performing poorly	1	2	3	4
17. My heart is racing.	1	2	3	4
18. I'm confident about performing well. . .	1	2	3	4

19. I'm worried about reaching my goal. . . . 1	2	3	4
20. I feel my stomach sinking. 1	2	3	4
21. I feel mentally relaxed. 1	2	3	4
22. I'm concerned that others will be disappointed with my performance. . .1	2	3	4
23. My hands are clammy. 1	2	3	4
24. I'm confident because I mentally picture myself reaching my goal. 1	2	3	4
25. I'm concerned that I won't be able to concentrate. 1	2	3	4
26. My body feels tight. 1	2	3	4
27. I'm confident of coming through under pressure. 1	2	3	4

APPENDIX B

INFORMED CONSENT FORM

University of Florida
Department of Exercise and Sport Science
Informed Consent

Project Title: Visual Search Processes During a Simulated Racecar Driving Task

Principal Investigators: Janelle, Christopher M., Graduate Student; Robert N. Singer, Ph.D., Professor and Chair, Department of Exercise and Sport Sciences, FLG 100, Phone: (352) 392-0584

This is to certify that I__________, hereby agree to participate as a volunteer in this scientific investigation as part of an authorized research program at the University of Florida, under the supervision of Robert N. Singer.

Purpose and Testing Procedures
The purpose of this study is to investigate the visual search patterns of participants as they perform a simulated driving task. A contrived competition will be derived in which subjects will compete with others on two separate test sessions. Upon arrival at the Motor Behavior Laboratory for testing, participants will be outfitted in visual search collection instrumentation and a heart rate monitor and then complete a short questionnaire that evaluates how they are feeling at that moment. They will then complete 20 laps on the simulated race course. The experiment will take approximately one hour per session for a total of two hours.

General Information
(a) The principal investigator will answer any of my questions about the research project and my rights as a volunteer subject.
(b) There is no more than minimal risk to my health and well being.
(c) I will receive experiment participation credit in the amount of 10 extra credit points which amounts to 1.25% of my final grade for volunteering.
(d) I am free to withdraw my consent and to terminate my participation at any time.
(e) If there are questions I do not wish to answer, I do not have to answer them.

(f) My data and answers to any questions will remain confidential to the extent provided by law. My identity will be withheld from data files, sheets, and analyses because a number coding system will be used. Only grouped data will be reported in any future publication.

(g) Questions or concerns about my rights as a participant can be directed to the UFIRB office, Box 112250, University of Florida, (352) 392-2556

I have read and /or discussed the procedure described above and I understand the procedure. There is no anticipated risk to participating in the experiment. I voluntarily agree to participate in the procedure and I have received a copy of this description.

Signature of Participant _______________ Date _________ Age _____

Signature of Witness _______________ Date _________ Age _____

I have defined and fully explained this study to the above named subject:

_________________________ __________

Signature of Principal Investigator Date

APPENDIX C

PRE-RACE INSTRUCTIONS

Please have a seat in the driver's chair and I will give you some preliminary instructions that will help you in learning how to drive the race car. Keep in mind that this is a difficult task so please do not get frustrated or discouraged but continue to try your best to get the hang of it. The steering wheel controls the direction of the car while the foot pedals you see mounted on the floor control the braking and acceleration functions of the race car. Just as in your car, the accelerator is on the right side and the brake is on the left.

You will be driving on an exact scale representation of the Michigan International Speedway. As you can see, it is an oval track and you will be going around the track to the left. Once again, your perspective will be as if you are sitting in the driver's seat of the race car. In front of you will be a dashboard with a variety of instruments. Of these instruments, the only one you will have to pay attention to is the speedometer which will be a digital readout at the bottom of the screen. When the race begins, you will be in Pit Row and your car will be rolling forward so do not bother hitting the accelerator. The maximum speed you can go through the Pit area is 80 mph and the computer will accelerate you that fast so there is no need to hit the gas pedal.

It is important to monitor your speed as you will want to maintain different speeds as you approach different parts of the track. The car can go up to 250 mph. However, when going around the curves, try to keep it around 200 mph. If you go much faster, the car will have a tendency to run into the outer wall. However, you'll notice that the turns are banked (meaning they're sloped to hold the car on the track at high speeds). For this reason, you do not want to go too slow as the sloped turns will tend to force the car down toward the infield. You can go as fast as you like down the straight-aways. However, keep in mind that you will have to slow down going into the turns.

One thing that will inevitably happen is that you will wreck. First of all, do not get discouraged when you wreck because everyone has. Second, there are a few things you should remember in order to recover from the wreck and begin racing again. Specifically, you will probably end up in the infield and possibly facing the wrong direction after a wreck. If this is the case, the computer will turn the car around so you are facing the correct direction and it will also start the car rolling again. Your only responsibility will be to gradually steer the car back onto the track and do so very gradually. Because the tires on these cars have no treads, driving on the infield grass is like driving on ice and if you turn too sharply this will probably result in another wipe out. One critical thing to remember at all times is *never hit the accelerator (gas pedal) until the computer has accelerated the car up to 80 mph or more*. If you do, it is very difficult to control the car. Another important factor to remember is that the steering wheel is very sensitive so a small turn of the wheel results in large turns of the car, especially when the car is going upwards of 200 mph.

You will be completing 20 laps around the track and will do so 5 at a time. Therefore, after you complete 5 laps, I will stop the race, check the HRM and then restart it. You will do this 4 times and then be finished with this session. Your objectives are to drive as fast as possible while minimizing the number of errors you make. An error constitutes any time you hit the wall, run into another race car, or run over the white line and into the infield.

APPENDIX D

FAMILIARIZATION SESSION INSTRUCTIONS

General Instructions. During this experiment you will be completing a study that will be used to understand the visual search patterns of people as they drive an automobile. Once seated at the driving apparatus, you will complete a driving task while wearing visual search monitoring equipment. In total, you will complete 60 laps around the simulated race track. These 60 laps will be divided among 3 sessions. Therefore, you will complete 20 laps per session. During each session, you will complete 5 laps, then after a short break, you will complete 5 more, and so-on until you complete 20 laps.

Anxiety Group. The first session, which you will complete today, is a familiarization session so that you can become accustomed to the driving apparatus and experimental conditions. The next time you come in you will have one more practice session and then a competition session. The practice session will be similar to the familiarization session in that your scores will not be counted toward your overall performance but will be recorded so we can make comparisons with other drivers. It will be the last opportunity to practice before the competition session.

Immediately following the practice session, you will complete a competition session in which your scores will be recorded and used to judge your performance against

other drivers. It is in your best interest to perform as well as possible during the competition session as you can win $50.00 if you are the best driver. Your performance will be determined through an equally weighted calculation of driving proficiency (as determined by lap speed and driving errors) [and for peripheral tasks] and peripheral light detection accuracy and speed. Therefore, try to drive as fast as possible without going off the track [and identify the lights as quickly and accurately as possible].

This is a familiarization session. Remember your goal is to drive as fast as possible without running into the walls, off the track, or into other cars. [(If performing the peripheral task) Also, remember that you must identify as quickly and accurately as possible, the presence of the red light by responding with the word "light". Your performance score will be determined by a combination of your driving speed and errors as well as how quickly and correctly you identify the lights. As both tasks are equally important to your overall score, you should try to perform both tasks as well as possible]. Though your score will not be included in the final standings, it will be evaluated by the experimenters and used to determine your eligibility for the $50.00 award. Remember, this is the last opportunity you will have to practice before the actual competition session. Are there any questions?

Control Groups. This is the first of three driving sessions. Remember your goal is to drive as fast as possible without running into the walls, off the track, or into other cars. [(If performing the peripheral task) Also, remember that you must identify as quickly and accurately as possible, the presence of the red light by responding with the word "light". Your performance score will be determined by a combination of your driving speed and errors as well as how quickly and correctly you identify the lights. As both tasks are

equally important to your overall score, you should try to perform both tasks as well as possible]. Remember, please try to perform the (two) tasks to the best of your ability. Are there any questions?

APPENDIX E

PRACTICE SESSION INSTRUCTIONS

Anxiety Group. This is a practice session. Remember your goal is to drive as fast as possible without running into the walls, off the track, or into other cars. [(If performing the peripheral task)] Also, remember that you must identify as quickly and accurately as possible, the presence of the red light by responding with the word "light". Your performance score will be determined by a combination of your driving speed and errors as well as how quickly and correctly you identify the lights. As both tasks are equally important to your overall score, you should try to perform both tasks as well as possible]. Though your score will not be included in the final standings, it will be evaluated by the experimenters and used to determine your eligibility for the $50.00 award. Remember, this is the last opportunity you will have to practice before the actual competition session. Are there any questions?

Control Groups. This is the second of three driving sessions. Remember your goal is to drive as fast as possible without running into the walls, off the track, or into other cars. [(If performing the peripheral task) Also, remember that you must identify as quickly and accurately as possible, the presence of the red light by responding with the word "light". Your performance score will be determined by a combination of your driving

speed and errors as well as how quickly and correctly you identify the lights. As both tasks are equally important to your overall score, you should try to perform both tasks as well as possible]. Remember, please try to perform the (two) tasks to the best of your ability. Are there any questions?

APPENDIX F

COMPETITION SESSION INSTRUCTIONS

Anxiety Groups. As you know this is the competition session which you have been practicing for. Your performance thus far has been relatively good -putting you in contention for the $50.00 reward. As you can see, we have plotted your average score in comparison to the other participants. Though close, you are slightly behind the leader at his point. You will have to run a virtually flawless race in order to win the prize money, but given your performance thus far, that is possible. Remember, the amount of extra credit that you receive for participating in the experiment depends on your performance in the competition session.

Also, I just received a call from the Discovery Channel and they were wondering if I could send them a tape of the experimental setup and an actual participant in the study. We routinely have requests for tapes and given your high performance, I was wondering if you would mind being taped as you drive.

Remember your goal is to drive as fast as possible without running into the walls, off the track, or into other cars. [(If performing the peripheral task) Also, remember that you must identify as quickly and accurately as possible, the presence of the red light by responding with the word “light”. Your performance score will be determined by a

combination of your driving speed and errors as well as how quickly and correctly you identify the lights. As both tasks are equally important to your overall score, you should try to perform both tasks as well as possible]. It is imperative that you do your best on both the driving and light identification tasks so Discovery has some interesting and useful data to report for the special, and so you receive credit for participating. Any questions?

Control Groups. As you know, this is the third and final session. Remember your goal is to drive as fast as possible without running into the walls, off the track, or into other cars. [(If performing the peripheral task) Also, remember that you must identify as quickly and accurately as possible, the presence of the red light by responding with the word "light". Your performance score will be determined by a combination of your driving speed and errors as well as how quickly and correctly you identify the lights. As both tasks are equally important to your overall score, you should try to perform both tasks as well as possible]. Please do your best on both the driving and light identification tasks. Any questions?

APPENDIX G

POST-EXPERIMENT COMMENTS

Relevant Anxiety

Knowing that I was actually competing against others made me feel more nervous because it made me want to do better and I was hoping I wouldn't crash moreso than if it was only an experiment.

Losing the extra credit points or not getting as much made me want to win more

They made me try harder and concentrate on doing my best.

Made me more nervous.

The competition was my main concern.

Made me more nervous and anxious and I wanted to do well. Before that I really didn't care.

Made me feel more competitive, but more nervous. I felt those factors helped me know I could do well.

Central Anxiety

I was nervous, shaking, and concentrating much harder.

They screwed me up - unconsciously.

They put more pressure on me and I felt dumb after - no big deal though.

I tried to convince myself "I'm not anxious" - and I usually felt mentally that I was doing a good job, but often my performance showed otherwise. The more I think about it, often the worse I perform.

Made me more anxious to do well - I'm very competitive by nature.

The more I was told, the more pressure I felt.

I felt more pressure to do well.

I became a lot more focused on how I was driving, trying not to make as many mistakes and avoiding ones I had already made. I became a more tense during the actual (competition) driving part but not before. Even though I was tense, I really began to enjoy driving more because I was more focused.

Distraction Anxiety

I felt pressure and stress.

Worked harder to get a better score.

These factors increased my nervousness and desire to do well once I sat in the driver's chair.

The part about not getting all of the extra credit points made me nervous, especially since I crashed at the end.

I felt more attention would be directed to the last session, and it affected my concentration in a negative way.

Made me try harder to better my driving and light perception.

They made me feel more insecure and unfocused at the wheel. Besides just thinking about the lights and the driving, I also had these other factors on my mind.

APPENDIX H

PEARSON PRODUCT-MOMENT SIMPLE CORRELATION COEFFICIENTS

	SPEED1	SPEED2	SPEED3	MINOR1	MINOR2	MINOR3	MAJOR1	MAJOR2	MAJOR3	EX1	EX2	EX3
SPEED1	1	.69**	.26	-.22	-.44**	-.17	-.78**	-.51**	-.18	.04	.11	.14
SPEED2		1	.41**	-.27	-.46**	-.13	-.40**	-.82**	-.26	-.15	.06	.15
SPEED3			1	-.13	-.32*	-.34*	-.05	-.17	-.76**	-.32	-.33	-.35*
MINOR1				1	.54**	.49**	.21*	.51**	.26	-.32	-.21	-.29
MINOR2					1	.69**	.27	.58**	.33*	-.13	-.12	-.15
MINOR3						1	.22	.27	.45**	-.17	-.18	-.17
MAJOR1							1	.38**	.13	-.25	-.27	-.26
MAJOR2								1	.22	-.09	-.18	-.27
MAJOR3									1	.07	.18	.21
EX1										1	.70**	.65**
EX2											1	.95**
EX3												1

Variable Names:

SPEED = Lap speed
MINOR = Minor errors
MAJOR = Major errors
HRCHANGE = Heart rate change
ANXIETY = Anxiety level
EX = Exogenous saccades
MISS = Misidentifications
RT = Response time

	HR CHANGE1	HR CHANGE2	HR CHANGE3	MISS1	MISS2	MISS3	ANXIETY 1	ANXIETY 2	ANXIETY 3	RT1	RT2	RT3
SPEED1	.16	.08	.11	-.05	-.10	.14	.01	-.05	.00	.15	.24	.27
SPEED2	.29*	.29*	.26	.24	.10	.10	.08	-.00	.07	.15	.02	.21
SPEED3	.21	-.11	-.18	-.03	-.29	-.55**	-.08	-.22	-.33*	-.06	-.30*	-.34*
MINOR1	-.09	-.07	-.02	.11	-.00	-.15	-.13	-.23	-.14	.02	.01	-.10
MINOR2	-.14	-.08	-.13	.08	-.15	-.27	-.11	-.19	-.14	.03	-.11	-.23
MINOR3	-.03	.01	.05	.21	-.13	-.25	-.23	-.24	-.01	.15	-.16	-.23
MAJOR1	.05	.04	.03	.17	-.05	-.18	-.00	.06	.02	-.15	-.37*	-.35*
MAJOR2	-.09	-.21	-.18	-.21	-.29*	-.28	-.10	-.13	-.17	-.15	-.16	-.32*
MAJOR3	-.09	.17	.18	.28	.25	.44**	.02	-.02	.09	.26	.24	.28*
EX1	-.24	-.19	-.13	.10	-.03	.14	-.06	-.05	.01	.23	.32*	.26
EX2	-.22	.14	.27	.12	-.05	.34*	-.13	.01	.24	.31*	.42*	.52**
EX3	-.16	.25	.37*	.18	.03	.43*	-.03	.14	.37*	.28	.37*	.56**
HRCHANGE 1	1	.43**	.34*	-.01	-.07	.00	.29*	.20	.23	-.26	-.32*	-.15
HRCHANGE 2		1	.86**	.34*	.40*	.48**	.12	.13	.35*	-.09	.08	.42*
HRCHANGE 3			1	.23	.43*	.63**	.03	.17	.56**	-.11	.17	.53**
MISS1				1	.21	.19	-.32*	-.09	-.16	.69**	.38*	.41*
MISS2					1	.61**	.23	.14	.24	.01	.30*	.46**
MISS3						1	.26	.34*	.48**	.08	.51**	.75**
ANXIETY1							1	.66**	.26	-.45*	-.36*	-.12
ANXIETY2								1	.64**	-.16	-.13	.12
ANXIETY3									1	-.28	.02	.33*
RT1										1	.61**	.41*
RT2											1	.84**
RT3												1

**Significant at the 0.01 level

* Significant at the 0.05 level

BIOGRAPHICAL SKETCH

Born on May 5, 1969, in Boston, Massachusetts, Christopher Matthew Janelle was raised by his parents, Jean and Fran Janelle. After graduating from St. Xavier high school in Cincinnati, Ohio, Chris earned his Bachelor of Arts degree from Miami University in 1991. He then attended Springfield College to pursue his Master of Science degree in sport psychology under the tutelage of Dr. Mimi Murray. Upon completion of this degree in 1993, Chris enrolled in the College of Health and Human Performance at the University of Florida as a Ph.D. candidate in motor behavior and was mentored by Dr. Robert N. Singer. He completed his dissertation and was awarded the Ph.D. degree in August 1997.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Robert N. Singer, Chair
Professor of Exercise and Sport Sciences

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

L. Keith Tennant
Associate Professor of Exercise and Sport Sciences

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

James H. Cauraugh
Associate Professor of Exercise and Sport Sciences

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Milledge Murphey
Associate Professor of Exercise and Sport Sciences

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Ira Fischler
Professor of Psychology

This dissertation was submitted to the Graduate Faculty of the College of Health and Human Performance and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August 1997

Dean, College of Health and Human Performance

Dean, Graduate School